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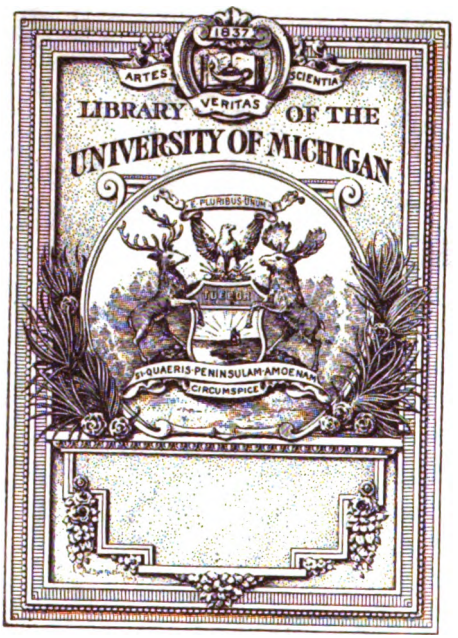
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E, Chemistry and Physics, 46

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

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# CONTRIBUTIONS TO MINERALOGY

FROM THE

## UNITED STATES GEOLOGICAL SURVEY

BY

F. W. CLARKE, W. F. HILLEBRAND, F. L. RANSOME, S. L. PENFIELD, WALDEMAR LINDGREN, GEORGE STEIGER, AND W. T. SCHALLER



WASHINGTON
GOVERNMENT PRINTING OFFICE
1905

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# LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
*Washington, D. C., January 31, 1905.*

SIR: I have the honor to transmit herewith a series of papers by various hands for publication as a bulletin. They represent mineralogical investigations incidental to geological researches and important to the progress of geology, and are here brought together for convenience of reference.

Very respectfully,

G. F. BECKER,
*Geologist in Charge Division of Chemical and Physical Research.*

Hon. CHARLES D. WALCOTT,
*Director United States Geological Survey.*



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# CONTRIBUTIONS TO MINERALOGY FROM THE UNITED STATES GEOLOGICAL SURVEY.

## PREFATORY NOTE.

By F. W. CLARKE.

Although mineralogical research occupies a relatively small place among the many varied activities of the United States Geological Survey, it is by no means neglected. From time to time interesting material is collected by the field parties of the organization, and specimens deserving study are received from other sources. These are worked up, as opportunity offers, in the chemical laboratory of the Survey, sometimes independently and sometimes, as in the work reported in two of the memoirs here presented, in cooperation with the geologists by whom they were brought in. Occasionally assistance is received from investigators not connected with the Survey, and one such case is now represented by the joint paper of Doctor Hillebrand and Professor Penfield, of Yale University. In that instance the chemical work was done in Washington and the crystallographic measurements were made at New Haven.

Most of the papers contained in this bulletin represent investigations which are complete within themselves. The work done by Mr. Steiger upon the silver and thallium derivatives of the zeolites, however, is to be regarded as one part of a series of researches upon the constitution of the silicates. Some parts of this series have been already published, and it is hoped that this work may be continued in the future. The field to be covered is enormous and progress within it is necessarily slow. Still, the results obtained so far are definite and significant, especially as they show a chemical plasticity among the silicates which was formerly unsuspected.

Some of the items of more than ordinary interest to be found within these pages are as follows: Three new mineral species—morencite, coronadite, and plumbojarosite—are described. Natrojarosite,



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although not absolutely new, is now thoroughly established as a definite mineral. The true character of carnotite is shown in Doctor Hillebrand's research, and the same chemist has worked out more fully than his predecessors the composition of yttrialite and its relations to other species. Mr. Schaller's very complete study of dumortierite is also worthy of especial mention, and his notes upon other minerals from California are but the first fruits of a much larger research which is already well under way.

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# ON CARNOTITE AND ASSOCIATED VANADIFEROUS MINERALS IN WESTERN COLORADO.

By W. F. HILLEBRAND and F. L. RANSOME.

## INTRODUCTION.

By W. F. HILLEBRAND.

The rather widespread occurrence in western Colorado of considerable quantities of a canary-yellow ore of uranium has been known for a few years past. It has been marketed to the extent of a few tons, but its mineralogical nature was unknown or incorrectly surmised until 1899.

In the spring of that year a specimen of this ore first reached my hands through Dr. George P. Merrill, of the United States National Museum, and was soon found to contain a mineral or minerals new to science. Within a week appeared the announcement by MM. C. Friedel and E. Cumenge[a] of a new mineral, carnotite, a hydrous vanadate of uranium and potassium, obtained through Mr. Poulot of Denver, from Roc Creek, Montrose County, Colo. Mr. Poulot had already identified vanadium in it. It was at once seen, despite certain differences in composition, that the two were identical.

According to the French authors the mineral is of simple composition, as above expressed, with only a little iron and mere traces of Al, Ba, Cu, Pb, and also, according to M. and Mme. Curie, of the radio-active substances radium and polonium. The empirical formula $2U_2O_3$, $V_2O_5$, $K_2O$, $3H_2O$, was assigned to it, some doubt attaching to the water.

Since then I have been able to examine carnotite from several localities in western Colorado, finding in each case the same lack of agreement with the analyses of Friedel and Cumenge.

While I was engaged in this work my attention was called to certain more or less greenish sandstones from the vicinity of Placerville on the San Miguel River, San Miguel County, Colo., which were said to be highly vanadiferous and of considerable extent, and in which a zone

[a] Bull. Soc. Chim. de Paris (3), xxi, 328, 1899; Bull. Soc. Franc. Min., xxii, 26, 1899; Comptes Rendus, cxxviii, 532, 1899; Chemical News, lxxx, 16, 1899. The papers as published in French differ slightly.



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a few inches thick was rather strongly impregnated with a yellow mineral resembling and probably identical with carnotite. This mineral appeared also scattered through the sandstone at other points in sporadic small patches, sometimes visible only by aid of a lens.

This occurrence led to the thought that the carnotite bodies farther west might also be associated with existing or dependent on preexistent vanadiferous sandstones. For the carnotite of Montrose and Mesa counties, as is stated by the French authors, occurs mixed in all proportions with quartz-sand grains, the remnants, beyond doubt, of former sandstone bodies, and it was soon recognized that in the carnotite bodies the vanadium existed in two conditions, the larger part by far as pentavalent vanadium in the easily soluble carnotite, and a smaller and sometimes hardly distinguishable portion as trivalent vanadium in a much less soluble silicate which was free from uranium.

It was hoped that, by a field reconnaissance, observations bearing on these points would be obtained and material assembled which would on analysis help to determine the nature and explain the association of these two entirely different classes of mineral substances.

The field and microscopical observations of Messrs. Ransome and Spencer are embodied in the pages immediately following these introductory remarks. Unfortunately their collections, except those from Placerville, came to hand so late that the chemical work on the more western occurrences has been confined to the carnotite bodies alone, specimens of which were already in my hands. Greenish sandstones have been observed by Messrs. Ransome and Spencer in those regions, but whether any of them are highly vanadiferous, or what their connection with the carnotite may be, remains yet unknown. The only two examined did not owe their color to vanadium. Meanwhile the chemical results thus far obtained will be found in the concluding section of this paper.

In this place it is my pleasure to record my appreciation of the readiness with which the following gentlemen have supplied me with material for study: Messrs. Poulot and Voillequé of Denver, Mr. A. B. Frenzel of Placerville, and Mr. J. R. Duling of Paradox. These gentlemen have also not hesitated to give me all information at their disposal as to occurrence and field relations of these interesting ore bodies.

## OCCURRENCE OF THE URANIUM AND VANADIUM ORES.

By F. L. Ransome.

### GENERAL STATEMENT.

In the autumn of 1899, accompanied by Dr. A. C. Spencer, whose knowledge of the stratigraphy of the region was of great assistance, I made a hasty reconnaissance trip into the western portions of San Miguel, Montrose, and Mesa counties, near the Utah-Colorado

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line. The primary object of the expedition, in accordance with a suggestion from Mr. S. F. Emmons, was to investigate the copper deposits of La Sal Creek, Paradox and Sinbad valleys, and the vicinity, which had been the occasion of some mining excitement a few months before. A memorandum from Dr. W. F. Hillebrand, received just before starting, indicated that it would be well also to examine certain prospects on which some preliminary work had been done, looking toward the extraction of ores of uranium and vanadium. It is to these ores that the present notes are confined.

The most convenient way of reaching Paradox Valley was found to be the stage road, which, starting from Placerville, a settlement and station on the Rio Grande Southern Railroad, runs by way of Norwood, Shenandoah, and Naturita to Paradox, a distance of 60 or 70 miles. The region can also be reached from the west by way of Moab, in Utah.

The topography of the region west of Placerville is that characteristic of the "mesa country" of western Colorado and southeastern Utah. Broad stretches of plateau are intersected by steep-walled canyons and cliff-encircled valleys. The underlying rocks comprise the "Red Beds" of the Dolores formation[a] (Triassic), the La Plata formation (Jurassic), the McElmo formation (Jurassic), the Dakota sandstone (Cretaceous), and the Mancos shales (Cretaceous). Carboniferous rocks occur in Sinbad Valley, and a series of gypsum-bearing shales of unknown age is found in the bottoms of Sinbad and Paradox valleys, but as the ore deposits to be described all occur in the beds of the La Plata and McElmo formations, these older rocks need not again be referred to. The sediments making up these various formations lie usually nearly horizontal, but they are sometimes flexed and frequently faulted.

In all of the prospects examined the ore of uranium occurs in the form of the recently described bright-yellow carnotite. In one case this is intimately associated with a dull olive-green mineral which, according to Doctor Hillebrand, is either identical with, or very closely allied to, the vanadium-mica roscoelite. Deposits of one or both of these minerals occur widely scattered over San Miguel and Montrose counties, Colo., and in the Blue Mountain (Sierra Abajo) district of southeastern Utah; but only a few of the known deposits were personally examined.

## PLACERVILLE DEPOSITS.

These are essentially vanadium deposits, and occur 4,500 feet nearly northeast of the railway station near Placerville, and about 1,000 feet above the San Miguel River. The lower 900 feet of the San Miguel

[a] The formation names used in these notes are those adopted by Mr. Whitman Cross in the text of the Telluride folio (folio 57), of the U. S. Geological Survey. The reader is referred to this folio for fuller descriptions.

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canyon is cut in the characteristic "Red Beds" of the Dolores formation. Above the Dolores comes the La Plata sandstone in typical development, as described in the Telluride folio, viz, two heavy beds of light-colored sandstone, separated by a much thinner bed of dark limestone. The roscoelite occurs as an impregnation in the lower bed of the La Plata sandstone, about 100 feet above the base, and just beneath the bed of dark limestone. All the beds at this point are practically horizontal. The dark green vanadiferous sandstone occurs in a nearly continuous band, approximately parallel to the bedding planes, and varying in thickness from a few inches up to 5 or 6 feet. This band extends along the sandstone cliffs for an estimated distance of about 2,000 feet. The roscoelite more or less thoroughly impregnates portions of the fine-grained sandstone which constitutes the mass of the bed. It sometimes makes up more than 20 per cent of the vanadiferous facies. Normally the sandstone of this lower bed of the La Plata is light buff in color, with patches, mottlings, and stripes of pale pink, the latter color being apparently due to small amounts of ferric oxide. But when richly impregnated with roscoelite this light-colored sandstone becomes dark olive-green, the contrast being most marked when the cliffs are wet. Although fairly continuous for the distance stated, this zone of vanadiferous sandstone is by no means regular. It varies much in thickness, and in one place splits into two or more branches. At some points two or more distinct streaks of roscoelite-bearing sand were found at different horizons in the main sandstone bed. The carnotite is not nearly so abundant as the roscoelite at this locality. It occurs as minute yellow specks in the sandstone, and particularly as thin horizontal seams or streaks near the bottom of the vanadiferous zone.

The work thus far done on the several claims which have been located along these deposits is of the most superficial character. On the Canary claim Mr. A. B. Frenzel has run a tunnel, about 18 feet long, which exposes a typical section of the impregnated zone. The roof of the tunnel is formed by the under side of the bed of dark limestone previously referred to. This limestone is underlain by a few inches of sandy limestone which passes into the light-buff La Plata sandstone without break. The latter contains abundant calcite as a cement or matrix for the sand grains. At a distance of a foot below the limestone, the sandstone shows, on close inspection, numerous specks of carnotite and gives a qualitative reaction for vanadium (Hillebrand). Examined in thin section under the microscope, this portion of the bed shows a fine-grained homogeneous sandstone, in which well-rounded grains of quartz are held together by a rather abundant matrix of calcite. The calcite is crystallized as a fine granular aggregate and includes small indeterminable particles of various kinds. Many of the quartz grains, as seen in section, are entirely surrounded by calcite, and so isolated from adjacent grains. A pale

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lemon-yellow substance occurs sporadically in the section as an interstitial material between the quartz grains. This is probably the carnotite, which was seen as small, yellow specks in the hand specimen. It is very minutely crystalline, recalling the habit of some obscure chloritic aggregates in decomposed igneous rocks, and is too indistinct for successful optical study. Small crystal grains of zircon are scattered through the sandstone, and are readily concentrated in the residue after treating with hydrofluoric acid.

Within the next 2 feet below the zone where it exhibits the foregoing facies, the sandstone becomes pinkish in consequence of the presence of ferric oxide, and in this pinkish rock the lens fails to reveal any roscoelite or carnotite. But just below the pink zone the sandstone begins to show yellow and green specks. The latter especially become more numerous and larger, until at from 3 to 4 feet below the limestone the sandstone has a decided green tint. Farther downward this deepens, until near the floor of the tunnel the sandstone is a uniform deep olive-green. This green rock is rich in roscoelite (over 20 per cent) and shows many small yellow specks of carnotite. This is regarded as the first-class ore, and the chief value of the deposit is supposed to be in its vanadium, the uranium being very subordinate. In this respect the Placerville deposit differs from those on La Sal and Roc creeks, presently to be described, where the mineral sought for and occurring most abundantly is carnotite.

Thin sections of the green-spotted sandstone, when examined microscopically, resemble those of the light-buff sandstone just above it, as far as character of quartz grains and relative abundance of matrix are concerned. But the character of the matrix or cement is different. Calcite is much less abundant and its place is largely taken by roscoelite. This is grass-green in thin section, and might readily be mistaken for indistinct wisps and areas of chlorite. It sometimes forms a distinct envelope around the quartz grains, showing an indistinct foliated or fibrous structure, with the fibers normal to the surface of the grains.

The uniformly dark-green sandstone, richest in roscoelite, does not effervesce with acids and shows no calcite cement in thin section. The usual quartz grains are held together by roscoelite. This is crystalline, but the highest available powers show only an indistinct and minute foliation, such as may be observed in some very finely crystallized chlorites.

Close to the floor of the tunnel is a fairly regular, nearly horizontal streak of carnotite, varying in width, but usually less than an inch wide, and showing noticeable diminution in thickness in the face of the tunnel. This small seam is not solid carnotite, but is merely a zone in the sandstone impregnated with the bright-yellow uranium mineral. It is not nearly so continuous as the main vanadiferous belt, and was seen only at three or four places along the outcrop of the

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belt, which extends for a distance of about 2,000 feet. When this seam is closely examined it is seen that narrow bands rich in carnotite alternate with green bands carrying mostly roscoelite. There is also usually present a seam of almost pure quartz, generally about an eighth of an inch in thickness, though often thicker. The microscope shows it to be a true quartzite, in which the original rounded detrital grains of quartz have been cemented by fresh quartz in optical continuity with the older granules. A similar quartzite occurs in the green vanadiferous sandstone above the carnotite, where it forms concretionary knots and nodules. It was not noted in the buff sandstone, however, where the cementing material is calcite.

Immediately below the carnotite seam there is a parting or "floor" in the sandstone, probably originally a very thin layer of shale, which forms the working floor of the tunnel. The sandstone below this floor is plainly impregnated for a short distance with roscoelite, but the thin shale seam is regarded as the practical bottom of the deposit.

The questions of the origin and actual extent of this deposit are closely related and are of much interest. Their discussion will be deferred until the other deposits visited have been described.

Some distance below the Placerville vanadium deposit a zone of green sandstone, presumably belonging to the Dolores formation, was observed. This color is a somewhat brighter green than that of the vanadiferous sandstone higher up the slope. As there are some copper prospects near by, from which ore has been taken, this was supposed to be a copper stain. Qualitative tests by Doctor Hillebrand show, however, that the color is due to a compound of chromium.

Similar green sandstones occur on the western side of Sinbad Valley in what is apparently the La Plata formation, and were originally supposed to be impregnated with roscoelite. Doctor Hillebrand's investigations, however, show that they too owe their color to some chromium mineral. These occurrences are interesting as showing that a green color in sandstones may result from various causes, and that even a bright green tint can not be taken as an infallible indication of copper.

## LA SAL CREEK DEPOSITS.

These occur in the extreme western portion of Montrose County, southwest of Paradox, and about 6 miles up La Sal Creek from Cashin. They are reached by trails from Paradox Valley and from Cashin. The deposits are on the south side of La Sal Creek and about 700 feet above the stream. They occur for a distance estimated at more than a quarter of a mile, along the sandstone cliffs which descend from the mesa into the canyon of La Sal Creek, and only a few feet below the level of the mesa surface.

In the absence of continuous stratigraphic work, it is impossible to correlate certainly and finally the rocks on La Sal Creek with the divisions established by Cross and Spencer in the Telluride quadrangle,

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which lies just east of this area. It seems probable, however, that the La Plata sandstone attains a much greater thickness in this portion of western Colorado than it does between Telluride and Placerville. The limestone bed, so characteristic a feature of the formation near Placerville and farther east, is not uniformly present in this western region, and the La Plata sandstone (Variegated beds, in part, of the Hayden survey) is not always readily differentiated from the underlying Dolores formation (Red Beds). For a vertical distance of about 400 feet above the bed of La Sal Creek the rock is a heavy-bedded, rather fine-grained, light-colored sandstone, which is considered by Doctor Spencer to be the La Plata. Above this come thinner-bedded sandstones, with some conglomerates and shales, which are included in the McElmo formation. It is in this upper series that the uraniferous deposits occur. All the beds are here approximately horizontal.

As revealed by numerous small openings near the crest of the bluff, the carnotite, which is the material here sought, is found chiefly in a massive bed of nearly white sandstone. Some of the ore, however, lies between the sandstone and a lower bed of light-gray shale. Although the prospecting openings all lie at about the same level along the cliffs, the deposit is not nearly so regular as the vanadiferous band near Placerville.

The carnotite of La Sal Creek occurs as irregular, bunchy "pockets" in the sandstone, or along the contact of the sandstone with the underlying shale. These have all the appearance of being impregnation deposits, the solutions carrying the uranium compounds having deposited the ore wherever they found ready passage through the rock—usually along bedding planes. No roscoelite was seen with the carnotite.

The most remarkable and interesting fact in regard to the La Sal Creek deposits is their very superficial character. The ore bodies are usually flat-lying streaks, a few inches thick, which grade above and below into the common light-buff sandstone, and which die out and disappear when followed into the hillside. In tunnels that run but a few feet underground the yellow impregnation of carnotite can be seen gradually to die out and to be succeeded by light-colored sandstone, showing no trace of the mineral. It is doubtful whether any appreciable quantity of carnotite occurs as much as 20 feet from the surface, on any of the locations, although this distance is given from memory and not from measurements on the ground. As before stated, the impregnation has usually taken place along bedding planes; it has also proceeded along surfaces of minor and superficial movement in the rocks. In one case it was observed that a portion of the overlying sandstone had moved upon the underlying shales, the disturbance being apparently a superficial one, of a kind commonly enough observed where massive beds rest on yielding shales on a steep hillside. In other words, the movement appeared to be directly related to the present topography. The carnotite was here deposited subsequent to

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the movement and had filled the small openings and dislocations in the shale caused by this very recent disturbance. It was reported that some of the best nests of ore had been found in "slide rock," i. e., rock which had slipped to some extent down the slope; but I was unable to verify this statement further than is indicated in the preceding description. There can be little doubt that the deposits of carnotite on La Sal Creek are not only very superficial in character but very recent in age.

### ROC CREEK DEPOSIT.

The principal claim is the Copper Prince, owned by J. R. Duling, on the north side of Roc Creek, 3 or 4 miles above its mouth, and near the foot of the Miller trail to Paradox. It is reached by this trail from Paradox Valley, or by trail from Hydraulic on the Dolores River. This deposit is in the La Plata sandstone, according to Doctor Spencer's observations, and has been more extensively exploited than any other seen. The sandstone, which at this point is nearly horizontal, is cut by an east-west fault, the fault plane dipping north at about 70°. The amount and character of the throw could not be determined. It is probably less than 50 feet. The carnotite occurs in the hanging wall of the fissure as small irregular branches in a loose mass of crushed sandstone and also as an impregnation of some of the firmer portions of the bed. No roscoelite was seen. Several small tunnels have been run in on the hanging wall side of the fissure (which itself carries no vein or ore-body), but they had been securely closed by planking, and no examination of their inner ends could be made. I am thus unable to tell what changes the deposit would show if it could be followed inward from the surface. A few hundred pounds of picked carnotite ore has been shipped from this claim and is reported to have sold for $1.25 a pound in Denver. This deposit is similar in character to others examined, except that in this case a well-defined fault has provided a zone of crushed and porous rock in the hanging wall, along which impregnation could take place. A few hundred feet farther west the crushed sandstone adjoining the fault has been impregnated with cupriferous solutions and is spotted with stains of the blue and green carbonates of copper.

### OTHER DEPOSITS.

It is known that several carnotite claims have been located in Gypsum Valley in what is known as the Disappointment district. The impregnated sandstone is said to cap a hill and to constitute an extensive deposit, but it was not visited. Carnotite is also reported from the Blue Mountain district, but I have no personal knowledge of these occurrences. It seems highly probable that the material will be found widely distributed in the Mesozoic sandstones of western Colorado and eastern Utah, although perhaps nowhere in very extensive bodies.

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## ORIGIN OF THE DEPOSITS.

That the bodies of carnotite and roscoelite were formed subsequently to the deposition of the sandstones is evident from the facts presented in the preceding pages. It is equally plain that the minerals could not have resulted from the alteration, in place, of other compounds of vanadium and uranium originally contained in the sands. The shape and position of the deposits indicate clearly that the ores have been brought to their present position by transportation. Moreover, the recency of the deposits and the fact that they are sometimes directly connected with faults and dislocations in the sandstones show that the vanadium and uranium compounds could not have been the original cementing material of the quartz grains, but in all probability they have locally replaced the calcite that acts as matrix to the ordinary light-colored sandstone in which the ore bodies occur. The deposits of roscoelite appear to be comparable to impregnations formed in sandstones by cupriferous solutions—such impregnations as may be seen at many places in this region, particularly on La Sal Creek near Cashin and in Sinbad Valley—whereby the sandstone becomes colored bright green with carbonate of copper. In these places, however, the copper appears to have been previously deposited in part as chalcocite. An analogy might also be drawn with the green chromiferous sandstone near Placerville, already referred to. In all these cases the actual sources of the materials which have been deposited by solutions in their present position are not known. Doctor Hillebrand has shown,[a] however, that vanadium in small amounts is widely distributed in sandstones, limestones, and igneous rocks. It is perhaps present in very small amounts throughout the sandstone, and the deposits described may simply represent a concentration of this material under certain favorable conditions of solution and redeposition.

In the absence of exploitation it is manifestly impossible to predict the probable shape and size of ore bodies formed in this manner. The roscoelite seen near Placerville appears, however, to be much more persistent than the carnotite. There is no apparent reason why a mass of sandstone, impregnated with roscoelite, which is continuously exposed for several hundred feet along a cliff, should not extend for a considerable distance inward from the cliff face. The carnotite, on the other hand, appears to be of much more superficial occurrence, and its connection with the present surface of the ground is not yet fully understood. This would indicate that the carnotite results from a local concentration of material already existent in the sandstone, and the deposition of this material in the form of carnotite under conditions determined by proximity to the surface, and probably partly dependent upon a semiarid climate.

[a] Am. Jour. Sci., 4th ser., vol. 6, 1898, pp. 209–216.



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## CHEMICAL ANALYSES AND DISCUSSION.

By W. F. HILLEBRAND.

### I. GREEN COLORING CONSTITUENT OF PLACERVILLE SANDSTONE.

As noted by Doctor Ransome, the greener the sandstone the greater has been the replacement of the calcareous cementing material by the crystalline vanadiferous mineral. Fortunately, the greenest available specimen was entirely free from carbonate, and this was used for analysis, 10 grams being taken for the main portion.

The green substance was but slightly attacked by cold acids and not rapidly by hot ones, nevertheless after from twelve to twenty-four hours' digestion on the water bath with diluted nitric acid the greenish color had been transferred to the liquid, the residue of sand was nearly white, and a rather voluminous separation of nongelatinous silica had taken place. The filtration and washing of the insoluble matter was accomplished without difficulty. The free silica in it was extracted by two or three digestions of fifteen minutes each on the water bath with sodium carbonate solution of 5 per cent strength. The flocculent matter had entirely disappeared and the sandy residue was collected in a Gooch crucible and washed with hot sodium carbonate solution, followed by very dilute nitric acid, and finally by alcohol, to prevent turbid filtration. Drying of the sand was effected by allowing the pump to draw air through the crucible until no further loss in weight resulted.

The water in the sand was then determined at 105°, at 300°, and above 300°. Similar water determinations having been made on the unattacked substance, the differences gave the water expelled at those temperatures from the soluble part.

The sodium carbonate solution was acidified, evaporated, and filtered, and the filtrate again evaporated, to recover the last of the silica. To this was added a very small portion which the nitric-acid extract of the sandstone held in solution. The sum represents the total silica of the decomposed portion of the sandstone.

The further analysis of the nitric solution presented difficulty because of the vanadium it contained. It was carried out in a variety of ways, of which the following seemed to be most satisfactory:

Barium was first precipitated by sulphuric acid and subsequently separated from traces of lead, calcium, and vanadium. Hydrogen sulphide then threw out further traces of lead and copper with much sulphur from reduction of $V_2O_5$ to $V_2O_4$. After evaporation of the filtrate to reoxidize vanadium and iron, the alumina, iron, and trace of uranium with much vanadium were separted from the calcium, magnesium, and alkalies by three precipitations by ammonia solution. The combined filtrates were evaporated and ignited, the residue was transferred to a porcelain boat with nitric acid, evaporated therein to complete dryness, and exposed in a glass tube to a current of dry

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hydrochloric-acid gas, as recommended by Smith and Hibbs[a] for the expulsion of vanadium from alkaline vanadates. The removal of vanadium being incomplete, the contents of the boat were again evaporated with nitric acid and again distilled, and these operations were repated till no further evidence of a brown distilate appeared. The boat now contained only magnesium and alkalies with a little calcium. The distillates, containing all the vanadium that was in the boat, had been collected in U-tubes charged with water, and were eventually obtained in sulphuric solution for further treatment by evaporating with sulphuric acid in porcelain.

The precipitate of $Al_2O_3$, etc., was dissolved in nitric acid, evaporated almost to dryness in platinum, and boiled with sodium-hydroxide solution. These operations were repeated on the precipitate after filtration. The iron and titanium thus purified were redissolved, precipitated by ammonia, weighed, redissolved by acid potassium sulphate, and the ferric iron was reduced by hydrogen sulphide and titrated with permanganate after boiling out the reducing agent. The titanium was then found colorimetrically by hydrogen peroxide.

The combined alkaline filtrates were heated with excess of ammonium nitrate to separate alumina from most of the vanadium. The precipitate was redissolved in nitric acid, reprecipitated by ammonia, then ignited and weighed and redissolved by acid potassium sulphate. The sulphuric solution was reduced by hydrogen sulphide, boiled and filtered from platinum sulphide, again boiled in a current of carbon dioxide, and titrated hot with permanganate. Sulphur dioxide gas was then introduced, boiled out in a current of carbon dioxide, and the titration repeated, this second result being taken as representing the $V_2O_4$ equivalent to the $V_2O_5$ that still contaminated the $Al_2O_3$. Deducting the $V_2O_5$ thus found from the combined weight of $Al_2O_3$ and $V_2O_5$ gave the $Al_2O_3$ of the soluble constituent of the sandstone.

The combined filtrates from the alumina were evaporated and ignited to remove ammoniacal salts; the residue was converted to sulphates and united with the earlier solution of vanadium sulphate. The vanadium in it was then determined precisely in the manner already described, and when added to that found with the alumina and calculated to $V_2O_5$ gave the total in the sandstone.

A check was made by dissolving the sandstone in hydrofluoric and sulphuric acids in a current of carbon dioxide and titrating the $V_2O_5$ with permanganate. The figure thus obtained was a trifle below that found as above detailed, and this is to be attributed to the presence of a very little vanadium as $V_2O_5$ in carnotite, and probably as a lead vanadate. All the uranium and most of the trifling amount of lead could be extracted by cold dilute nitric acid, showing that they were foreign to the green substance.

[a] Jour. Am. Chem. Soc., vol. 16, 1894, p. 578.

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It is preferable to regard iron as in the ferric rather than the ferrous state; otherwise an equivalent amount of vanadium would have to be considered as $V_2O_5$, for which there is no occasion. It is quite possible that the iron is in part, if not wholly, foreign to the green matter, for it would be surprising to find an exposed sandstone free from ferric oxide.

If the iron is disregarded as probably extraneous, the ratios given below afford the following empirical formula:

$$H_{396}\ R'_{194}\ R''_{39}\ R'''_{610}\ Si_{763}\ O_{2775}.$$
$$\text{or, } H_{396}\ R'_{194}\ R''_{39}\ R'''_{610}\ (SiO_4)_{555}\ (Si_3O_8)_{69}.$$
$$\text{Simplified, this is } H_{40}\ R'_{20}\ R''_{4}\ R'''_{61}\ X_{62.4}.$$

In view of the fact that the mineral is probably not perfectly pure and of the uncertainties affecting the amount of water to be considered, etc., the above affords a close approach to the typical phengitic muscovite formula, $H_2KR'''_3X_3$, in which X comprises the groups $SiO_4$ and $Si_3O_8$.

| | Sandstone. | Ratios. | | Silicate. | Roscoelite. |
|---|---|---|---|---|---|
| Soluble in nitric acid: | | | | | |
| $SiO_2$ | 12.56 | 0.763 | | 46.06 | 45, 17 |
| $TiO_2$ | .02 | | | | .78 |
| $V_2O_3$ | [a] 3.50 | .0846 | 0.305 | 12.84 | 24.01 |
| $Al_2O_3$ | 6.15 | .2206 | | 22.55 | 11.54 |
| $Fe_2O_3$ | .20 | .0046 | | .73 | FeO 1.60 |
| CaO | .12 | .0078 | .039 | .44 | |
| BaO | .37 | .0088 | | 1.35 | |
| MgO | .25 | .0228 | | .92 | 1.64 |
| $K_2O$ | 2.41 | .0938 | .097 | 8.84 | 10.37 |
| $Na_2O$ | .06 | .0035 | | .22 | .06 |
| $H_2O$ at 105° | .54 | .1100 | | 1.98 | .40 |
| $H_2O$ at 105°–300° | .14 | .0283 | | .51 | .17 |
| $H_2O$ above 300° | .97 | .1978 | .198 | 3.56 | 4.12 |
| $UO_3$ | .05 | | | | |
| PbO | .06 | | | | |
| $V_2O_5$ | .05 | | | | |
| Insoluble in nitric acid: | | | | | |
| Quartz, etc | [b] 72.24 | | | | |
| $H_2O$ at 105° | .04 | | | | |
| $H_2O$ above 105° | .20 | | | | |
| | 99.93 | | | 100.00 | 99.86 |

[a] Oxidation by permanganate of the HFl and $H_2SO_4$ solution of the sandstone indicated 3.43 per cent $V_2O_3$ (mean of 3.50, 3.32, 3.48, 3.43).

[b] Containing about 65 per cent $SiO_2$, 7 per cent $Al_2O_3$ ($Fe_2O_3TiO_2$) and about 0.3 per cent of zircon and other minerals not decomposed by repeated evaporations with HFl and $H_2SO_4$.

Traces of Li, Cu, Mo, Bi. No Cl, $SO_3$, or $P_2O_5$.

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An attempt to satisfactorily distribute the constituents among different chemical molecules would be futile, since, for instance, we do not know whether to ascribe the barium to a biotite or muscovite molecule, but the close approach to the muscovite ratio leaves little room to doubt the character of the body. Notwithstanding the chloritic aspect of the mineral under the microscope, the analysis shows that it can not be a chlorite, and we have undoubtedly to do with a body closely related to the mica roscoelite, wherein, however, the percentage proportions of $Al_2O_3$ and $V_2O_3$ are reversed, thus affording a further striking example of the mutual replaceability of these two oxides.

For comparison, the latest analysis of roscoelite from Placerville, Cal., is included in the above table. Peculiar, though unimportant, is the coincidence that the only two known localities for this mineral should bear the name Placerville.

## II. GREEN SANDSTONE COLORED BY CHROMIUM.

Other sandstones that were a much brighter green than the vanadiferous one were observed and collected by Doctor Ransome, both at Placerville and 60 miles distant in Sinbad Valley. The color suggested a salt of copper as its cause, but analysis showed it to be due to chromium. Time has not been found to determine the nature of this coloring body. It is very difficultly soluble, and thus presents greater hindrance to analysis than did the vanadium compound. It would be interesting to find that it is a micaceous mineral analogous to the one just described. Under the microscope it presents a chloritic appearance (Ransome). If opportunity offers, the problem of its nature may yet be attacked.

In still another greenish sandstone from the west bank of the Dolores River, near the mouth of La Sal Creek, analysis failed to show either vanadium or chromium.

## III. CARNOTITE ORES.

### OPTICAL EXAMINATION.

Dr. George P. Merrill has kindly submitted the following notes:

The carnotite powder appears under the microscope in the form of exceedingly minute dust-like particles without crystal outlines and acting so faintly on polarized light as to at first seem almost amorphous. Much of the matter appears merely as a fine brownish clay, stained yellow by an amorphous pigment, but occasionally a well-defined fragment of a light-yellow translucent mineral is seen, which doubtless represents the vanadium compound in its condition of ideal purity.

Working over a considerable amount of the powder I have found occasional clusters of this yellow mineral in the form of flattened radiating crystals with pyramidal terminations which are without evident pleochroism, polarize only in dull colors, and give extinctions always parallel to the axis of elongation. These are so minute (not over 0.25 mm. in length) and so thin that I have never been able to find a crystal so oriented as to give an opportunity of determining its exact character, and I can only say that the general shape is such as to suggest a hexagonal mineral, though this is by no means certain.

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## CHEMICAL EXAMINATION OF CARNOTITE ORES.

The chemical problems involved in the analysis of the carnotite ores were peculiarly intricate. Ideal material was quite unobtainable and mechanical separation was impossible. The first specimen received happened to be of higher grade than any of the subsequent ones, containing about 5 per cent of sand grains and showing only very faint delicate reddish tracings, indicative of some foreign iron mineral. In mass it was of a beautiful canary-yellow color and easily broken down by pressure. Other specimens were more coherent, the degree depending altogether on the extent to which the sandstone had been impregnated and altered, and they sometimes showed more of the peculiar reddish admixture.

A fact only suspected in making the first analysis was confirmed by subsequent work on lower-grade ores, namely, that the vanadium existed in two conditions, in entirely distinct minerals, the greater part by far as pentavalent vanadium in the easily soluble carnotite, and a smaller, much less soluble portion, almost vanishing in the purest ores, in the trivalent state as a constituent of a silicate free from uranium. This observation explained the statement of Messrs. Poulot and Voillequé that they had found the low-grade ores relatively richer in vanadium, as compared with uranium, than the high-grade ores.

While the carnotite dissolves at once in cold dilute nitric acid, unfortunately the vanadiferous silicate is not quite insoluble, hence arose an important difficulty in the way of arriving at the true composition of the carnotite. It is true that in one case the silicate has been analyzed (p. 30), but it would be unsafe to correct the carnotite analysis on that basis. Moreover, the analyses were not all made on the same plan; some are less complete than others; they can not in some respects be rigidly compared with one another.

As to the carrying out of the analysis, various procedures were tried and no one was found which gave altogether satisfactory results as to each constituent, though many could be determined with the usual degree of accuracy. The difficulty was due mainly to vanadium and the small amount of phosphoric acid usually present. These two constituents were likely to be found in different precipitates and could not be separated from them at one stroke. Their complete removal from other bodies was at times impossible, and the weight of the latter had then to be corrected for these residual amounts.

Two entirely different lines of attack were open. One, that of Friedel and Cumenge, described in their paper on carnotite, had already been used with apparent success. It depends on rendering the vanadium insoluble in water by evaporating the nitric acid solution to dryness. Water extracts the alkalies and uranium without

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dissolving the vanadium, iron, or aluminum. Repetition of this process yielded Friedel and Cumenge satisfactory results. They recommended washing with water containing ammonium nitrate.

The other method involved the quantitative removal of vanadium by dry hydrochloric acid gas in the manner already described (pp. 18–19). Smith and Hibbs had shown that this method is perfect for alkaline pyrovanadates and it was hoped that it might succeed even with such complex mixtures as those under consideration. The distillations were made on the crude ore and also on the nitric acid solution after filtration from the insoluble matter and evaporation to thorough dryness. The action is immediate in the cold, copious red-brown vapors coming off and condensing in part as a dark red liquid in the tube. But repeated distillations and the application of heat were required to effect complete removal of the vanadium accompanied by the arsenic and molybdenum. After each distillation the contents of the boat had to be evaporated with nitric acid. The blue and green colorations apparent on adding this acid showed that the hydrochloric acid gas had reduced a good deal of the vanadium to a lower state of valence, and in this condition it was incapable of forming the volatile body.

A somewhat more satisfactory separation sometimes resulted when this distillation method was combined with that of Friedel and Cumenge by subjecting both the evaporated uranium nitrate solution and the residue insoluble in water to the action of hydrochloric acid gas.

The distillates obtained by either way were evaporated with sulphuric acid, the arsenic and molybdenum were separated by hydrogen sulphide, and the vanadium was then titrated by permanganate at a temperature near boiling and again after reduction by sulphur dioxide gas. In one or two cases when the temperature of distillation had been high and it was feared some iron had passed over, the distillates were evaporated in porcelain with nitric acid, transferred to a platinum crucible, evaporated therein with sulphuric acid, and fused with sodium carbonate. The aqueous extract was then treated as above for arsenic, molybdenum, and vanadium.

The mode of separation practiced by Friedel and Cumenge, while perhaps adequate for technical purposes in ores free from phosphorus,[a] does not in my hands give perfect satisfaction even then. It is impossible to prevent a little of the vanadium, also of the iron and aluminum, from going with the uranium, and on the other hand a little uranium may stay with the vanadium. Again when the vanadic acid

[a] With even only half a per cent of $P_2O_5$ many times that amount of $UO_3$ is rendered insoluble in water after evaporation to dryness with nitric acid. The compound formed is of a lemon-yellow color, which is masked by the separated vanadic acid until this has been removed by ammonia. This insoluble body was treated as follows in order to arrive at the $P_2O_5$ and $UO_3$ it contained. After solution in nitrite acid the phosphorus was precipitated by ammonium molybdate, and from the filtrate the uranium by three precipitations by ammonia.

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is extracted from the residue by ammonia, as prescribed by Friedel and Cumenge, a little of the other constituents of the residue accompany the vanadium into solution.

If the combination of the two methods is used, it is better, after the vanadium has been removed by distillation, to treat the two residues separately at first instead of to unite them at once. Full details of this treatment are unnecessary and would unduly extend this paper. Suffice it to say that from the uranium portion the little iron and aluminum present are separated by ammonium sulphide and carbonate, and after removal of the latter and acidification the uranium can be thrown down by ammonium sulphide, and then by at least two precipitations by ammonia, or far better, by precipitating the neutral hydrochloric solution by freshly precipitated and alkali-free mercuric oxide at boiling heat, as prescribed by Alibegoff.[a] As pointed out by von Foullon and also by Alibegoff, contrary to certain still widely disseminated statements, ammonium sulphide does not afford a good separation of uranium from calcium. This is perhaps especially true if the solution contains any phosphorus. Again, contrary to another statement, it seems perfectly possible to separate uranium completely from alkalies by a few ammonia precipitations.

The finally ignited and weighed $U_3O_8$ was redissolved in nitric acid, filtered, if necessary ($SiO_2$, $Al_2O_3$, $Fe_2O_3$), and divided into two parts, one of which was tested for the very little $P_2O_5$ usually present, and the other for vanadium by conversion into sulphate, reduction by sulphur dioxide gas, and titration by very dilute permanganate solution.

ANALYSES OF CARNOTITE ORES.

I. Copper Prince claim, Roc Creek, Montrose County, Colo.

According to the donor of the specimen, Mr. J. R. Duling, I–*a* is from the same lot as that from which Mr. Poulot obtained the specimens afterwards analyzed by Friedel and Cumenge.

II. Yellow Boy claim, La Sal Creek, Montrose County, Colo.

III. Yellow Bird claim, La Sal Creek, Montrose County, Colo.

The last two claims belong to the same group and the ore is from the same "blanket" (Voillequé).

I–*b* and II–*b*, the first analyses made, are not strictly comparable with the other analyses, since they represent the effect of warm dilute hydrochloric acid, whose greater action is shown by the nearly complete solution of the ferruginous admixture. Cold, dilute nitric acid was used for the other analyses.

[a] Ann. Chem. u. Phar., vol. 233, 1886, p. 133; Zeit für anal. Chemie, vol. 26, 1887, p. 632.

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| | I. | | | II. | | III. |
|---|---|---|---|---|---|---|
| | *a.* | *b.* | *c.* | *a.* | *b.* | |
| Insoluble | [a] 7.10 | [b] 8.34 | [c] 19.00 | [d] 10.33 | (*e*) | (*f*) |
| $UO_3$ | 54.89 | 52.25 | 47.42 | 54.00 | 52.28 | 20.51 |
| $V_2O_5$ | 18.49 | 18.35 | 15.76 | 18.05 | 17.50 | 7.20 |
| $P_2O_5$ | .80 | .35 | .40 | .05 | trace | none |
| $As_2O_5$ | trace | .25 | none | none | none | none |
| $Al_2O_3$ | .09 | (?) | .08 | .29 | (?) | .08? |
| $Fe_2O_3$ | .21 | 1.77 | .72 | .42 | 3.36 | .25 |
| CaO | 3.34 | 2.85 | 2.57 | 1.86 | 1.85 | 1.64 |
| SrO | .02 | (?) | (?) | trace | trace | (?) |
| BaO | .90 | .72 | .65 | 2.83 | 3.21 | .29 |
| MgO | .22 | .20 | .24 | .14 | .17 | .07 |
| $K_2O$ | 6.52 | 6.73 | 6.57 | 5.46 | 5.11 | 1.51 |
| $Na_2O$ | .14 | .09 | .07 | .13 | .02? | .01 |
| $Li_2O$ | trace | (?) | (?) | trace | (?) | (?) |
| $H_2O$ at 105° | 2.43 | 2.59 | 1.85 | 3.16 | 4.52 | 1.85 |
| $H_2O$ at 350° | 2.11 | 3.06 | 2.79 | 2.21 | 3.49 | [g] 1.64 |
| $H_2O$ above 350° | none | none | none | none | ..... | [h] .19 |
| PbO | .13 | .25 | .18 | .07 | ..... | .09 |
| CuO | .15 | .20 | .22 | trace | ..... | trace |
| $SO_3$ | none | .12 | .18 | none | ..... | none |
| $MoO_3$ | .18 | .23 | .18 | .05 | ..... | .04 |
| $SiO_2$ | .15 | .06 | .13 | .20 | ..... | .07 |
| $TiO_2$ | .03 | .10 | (?) | (?) | ..... | .06? |
| $CO_2$ | .56 | .33 | none | none | ..... | ..... |
| | 98.46 | 98.84 | 99.01 | 99.25 | ..... | ..... |

[a] Containing 0.54 $H_2O$, 0.09 $V_2O_3$.

[b] The insoluble matter had the following composition: $SiO_2$, 5.18; $V_2O_3$, 0.21; $P_2O_5$, 0.09; $K_2O$, 0.26; $Na_2O$, 0.04; $H_2O$, 105°, 0.56, 350°, 0.32, +350°, 0.48; $Al_2O_3$, $TiO_2$, $Cr_2O_3$, etc., by diff., 1.20. The $SO_3$ of this ore is not combined with BaO, for it is wholly extracted by dilute acids. Once in solution the acid used is sufficient to prevent its immediate precipitation as $BaSO_4$ by union with some of the barium present. The same holds true for the $SO_3$ of I–*c*.

[c] This material was obtained by floating off the finer matter, allowing it to settle, collecting on a Gooch filter, and drying it in a current of air drawn through the crucible. The insoluble matter held in addition to 16.41 quartz and silicates (including 0.39 $V_2O_3$ and a little $UO_3$), $H_2O$, 105°, 0.83; 300°, 0.73; +300°, 1.03; total $H_2O$, 2.59.

[d] Containing 0.16 $V_2O_3$ and 1.90 $H_2O$.

[e] The insoluble matter contained besides quartz and silicates: 0.25 $V_2O_3$, 0.21 $K_2O$, 0.05 $Na_2O$.

[f] This analysis was made purposely on a relatively poor ore, furnished by Messrs. Poulot and Voillequé, with the object of determining, if possible, the composition of the vanadiferous silicate which it contained (see p. 30). The data for calculating the $H_2O$ values of both analyses are as follows:

| | Ore. | After extraction of carnotite by cold, dilute nitric acid. | After extraction of residue by hot nitric acid, sodium carbonate, etc. |
|---|---|---|---|
| | (*a*) | (*b*) | (*c*) |
| $H_2O$ at 105° | 3.53 | 1.68 | 0.02 |
| $H_2O$ at 300° | 2.11 | .47 | .03 |
| $H_2O$ above 300° | .83 | .64 | .02 |
| | 6.47 | 2.79 | .07 |

*a*–*b* furnishes the values for the carnotite as shown in analysis III; *b*–*c* gives those for the less soluble silicate (p. 30).

[g] At 300°.

[h] Above 300°.

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## DISCUSSION OF THE CARNOTITE ANALYSES.

It will be noted that a somewhat marked deficiency appears in most of the analyses, the cause of which is quite unknown. Great care was exercised in most cases and especially in those which show the greatest loss. It seems hardly possible that any serious constant loss of a known constituent should have occurred, but the only alternative demands the presence of an element or elements unnoticed and which can not have been weighed with the known constituents. The researches of M. and Mme. Curie have shown that these ores contain traces of radio-active elements, precipitated the one by hydrogen sulphide, the other by sulphuric acid. Their presence, however, in quantity sufficient to account for the observed losses in the above analyses, especially when 10 grams of ore were operated on, could not possibly have escaped observation. To whatever cause it may be due, this loss alone suffices to render somewhat uncertain any calculations based on the analytical figures, though if the loss is to be ascribed to uranium or vanadium the ratios would not be sufficiently affected to obscure any simple relations that might exist.[a]

Another difficulty is the impossibility of knowing what constituents to exclude and what to include in deducing molecular ratios. It is certain that most if not all of the iron is foreign to the yellow body. It is probable that phosphorus is likewise so, since its extraction by dilute acids does not keep pace with that of the uranium and vanadium. It may possibly be in combination with the iron, in part at least. The alumina doubtless is derived from the vanadiferous silicate which seems to exist in all the ores and which is not quite insoluble in cold dilute acids. If so, a small portion of the vanadium, potassium, magnesium, and water are to be attributed to this mineral, but a general correction based on the analysis of this compound (see p. 30) would not be justifiable. Its application leads to nothing definite, even in the case of the particular ore No. III, from which the silicate analyzed was derived.

In the following tables are given first the recalculated analyses and then the molecular ratios. All those constituents have been excluded which pretty certainly do not belong to the carnotite, but small portions of some of those retained are unquestionably extraneous. In two cases (I–*a* and I–*b*) a certain proportion of lime has been arbitrarily excluded equivalent to the acid anhydrides $CO_2$, $MoO_3$, and $SO_3$, less what is needed to offset PbO and CuO.

[a] According to Dr. Harry C. Jones, of Johns Hopkins University, who very kindly undertook to examine a specimen of the Copper Prince ore for rare gaseous elements, helium is not present. Faint hydrogen lines were observed, the source of which was ascribed to water vapor. Other lines, due probably to hydrocarbons, were fairly strong, but the specimen had been long enough exposed in our laboratory and elsewhere to have accumulated enough dust to account for them.

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CARNOTITE ANALYSES RECALCULATED.

| | I-*a*. | I-*b*. | I-*c*. | II-*a*. | II-*b*. | III. |
|---|---|---|---|---|---|---|
| $V_2O_5$ | 20.72 | 21.09 | 20.12 | 20.54 | 19.85 | 20.62 |
| $P_2O_5$ | .90 | .40 | .51 | .06 | ..... | ..... |
| $As_2O_5$ | ..... | .29 | ..... | ..... | ..... | ..... |
| $UO_3$ | 61.53 | 60.06 | 60.55 | 61.44 | 59.31 | 58.75 |
| CaO | 3.03 | 2.77 | 3.28 | 2.11 | 2.10 | 4.70 |
| BaO(SrO) | 1.03 | .83 | .83 | 3.22 | 3.64 | .83 |
| MgO | .25 | .23 | .31 | .16 | .19 | .20 |
| $K_2O$ | 7.31 | 7.73 | 8.39 | 6.21 | 5.80 | 4.33 |
| $Na_2O$ | .15 | .10 | .09 | .15 | .02 | .03 |
| $H_2O-105°$ | 2.72 | 2.98 | 2.36 | 3.59 | 5.13 | 5.30 |
| $H_2O+105°$ | 2.36 | 3.52 | 3.56 | 2.52 | 3.96 | 5.24 |
| | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

MOLECULAR RATIOS.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $V_2O_5$ | 1133 | 1196 | 1208 | 1248 | 1101 | 1137 | 1124 | 1128 | 1081 | | 1128 | |
| $P_2O_5$ | 63 | | 28 | | 36 | | 4 | | ..... | | ..... | |
| $As_2O_5$ | ..... | | 12 | | ..... | | ..... | | ..... | | ..... | |
| $UO_3$ | 2140 | | 2088 | | 2105 | | 2136 | | 2062 | | 2043 | |
| CaO | 541 | 671 | 495 | 606 | 586 | 718 | 377 | 627 | 375 | 660 | 839 | 943 |
| BaO(SrO) | 68 | | 54 | | 54 | | 210 | | 238 | | 54 | |
| MgO | 62 | | 57 | | 78 | | 40 | | 47 | | 50 | |
| $K_2O$ | 776 | 809 | 826 | 848 | 891 | 911 | 659 | 692 | 616 | 620 | 460 | 466 |
| $Na_2O$ | 33 | | 22 | | 20 | | 33 | | 4 | | 6 | |
| $H_2O-105°$ | 1511 | | 1656 | | 1311 | | 1994 | | 2850 | | 2944 | |
| $H_2O+105°$ | 1311 | | 1956 | | 1978 | | 1400 | | 2200 | | 2911 | |

These ratios lead to the following empirical formulas, in which only the water given off above 105° is considered. Since the water is wholly removable below 350° it is regarded as water of crystallization and not of constitution.

| | R'. | R''. | R$^v$. | U. | O. | $H_2O$. |
|---|---|---|---|---|---|---|
| I-*a* | 1618 | 671 | 2392 | 2140 | 13880 | 1311 |
| I-*b* | 1696 | 606 | 2496 | 2088 | 13958 | 1956 |
| I-*c* | 1822 | 718 | 2274 | 2105 | 13629 | 1978 |
| II-*a* | 1384 | 627 | 2256 | 2136 | 13367 | 1400 |
| II-*b* | 1240 | 660 | 2162 | 2062 | 12871 | 2200 |
| III | 932 | 943 | 2256 | 2043 | 13178 | 2911 |

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If it be assumed that the bivalent elements offer the most accurate determinations, the above ratios may be reduced to the following simpler terms on that basis:

| | R′. | R″. | R$^{v}$. | U. | O. | $H_2O$. |
|---|---|---|---|---|---|---|
| I–*a* | 2.41 | 1 | 3.56 | 3.19 | 20.68 | 1.95 |
| I–*b* | 2.80 | 1 | 4.12 | 3.45 | 23.03 | 3.23 |
| I–*c* | 2.54 | 1 | 3.17 | 2.93 | 18.98 | 2.75 |
| II–*a* | 2.21 | 1 | 3.60 | 3.41 | 21.32 | 2.23 |
| II–*b* | 1.88 | 1 | 3.27 | 3.12 | 19.50 | 3.33 |
| III | .99 | 1 | 2.39 | 2.16 | 13.98 | 3.09 |

The results, however, show a great lack of agreement and wide variation. It is plain that no probable formula can be calculated for the yellow body. The variations are of such a nature as to indicate in the plainest manner that it is a mixture of several substances.

So detailed a discussion as the foregoing would hardly have been justified, in view of the negative conclusions arrived at, but for the fact that Messrs. Friedel and Cumenge in their paper announced a simple formula for the body examined by them and gave it the specific name carnotite. Their published analyses are as given below, from which they have excluded considerable sand and traces of barium, aluminum, lead, copper, and radio-active bodies as present in excessively small quantities. They make no mention of calcium and admit that their values for water are open to doubt. The formula deduced by them is $2U_2O_3$,[a] $V_2O_5$, $K_2O$, $3H_2O$.

| | Found. | | | | Calculated. |
|---|---|---|---|---|---|
| | 1. | 2. | 3. | 4. | |
| $U_2O_3$[a] | 64.70 | 62.46 | ..... | ..... | 63.54 |
| $V_2O_5$ | 20.31 | 19.95 | ..... | ..... | 20.12 |
| $K_2O$ | 10.97 | 11.09 | ..... | ..... | 10.37 |
| $H_2O$ | ..... | ..... | 5.29 | 4.81 | 5.95 |
| $Fe_2O_3$ | .96 | .65 | ..... | ..... | ..... |
| | ..... | ..... | ..... | ..... | 99.98 |

[a] Old notation, equivalent to the modern $UO_3$.

It appears from these analyses that Messrs. Friedel and Cumenge by great good fortune obtained a variety of samples of the pure potassium compound, free from calcium and without appreciable admixture of

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barium. This is very remarkable in view of the fact that all the ores from different localities, examined by me show large admixture of calcium or barium salts or both, even that which is certified to have come from the same lot as that from which their material was taken. The French authors give a brief outline of their methods of analysis. That one which afforded them the best results would involve the weighing of any calcium present as sulphate along with the potassium, on the assumption that the presence of that element had been overlooked. It is much to be desired that a reanalysis of their material should be made, if there is any of it still available, in order to clear up the doubt connected with the first analysis.

In the light of the evidence herein set forth, the existence of a distinct mineral species having the composition claimed for carnotite can by no means be considered as established.

### AVERAGE QUALITY OF MARKETED ORE.

As these carnotite ore bodies are being exploited for the market, it is of some interest to know the average quality of each commercial lot. A carefully prepared sample representing several tons of ore was received from one of the commercial houses of Denver and was found to carry 11.49 per cent of uranium counted as $U_3O_8$, and 6.40 per cent of vanadium counted as $V_2O_5$. Over one-sixth of the vanadium existed, however, in the trivalent state, not as a constituent of the yellow body, but doubtless of a silicate like the one whose composition is given on page 30.

### COMMERCIAL ASSAY.

The commercial assay of these ores has presented difficulties to the technical chemist, the results being sometimes very discordant.

As to uranium, this is not surprising. The methods that have probably been commonly employed will give varying results, according to the contents of the ore in phosphorus and alkaline earths. Possibly the old Patera process, described in most text-books on analytical chemistry, might be made to serve, with modifications called for by the large amount of vanadium present.

The assay for vanadium presents little difficulty and does not require much time. The ore is fused with sodium carbonate, leached with water, and the fusion repeated on the residue. The combined filtrates are acidified by sulphuric acid, arsenic and molybdenum are precipitated in the hot solution by hydrogen sulphide, whereby the $V_2O_5$ is reduced to $V_2O_4$. After filtration and expulsion of hydrogen sulphide by boiling, the vanadium is titrated in hot solution by permanganate. It is then reduced by sulphur dioxide gas, and after boiling this out the titration is repeated. The results are exact, and they are not affected by the uranium that may be present.

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## IV. COMPOSITION OF VANADIFEROUS SILICATE IN CARNOTITE ORE.

As already mentioned, the ores contain a vanadiferous silicate free from uranium. To the end of ascertaining its composition, if possible, ore No. III (p. 25), from the Yellow Bird claim, low in carnotite, but relatively rich in vanadium, was treated as follows:

The carnotite from 10 grams was extracted by cold, dilute nitric acid, and the well-washed residue, consisting of coarse sand and an utterly amorphous mud, by 4 per cent sodium carbonate solution to get rid of the small amount of silica presumably set free, but not dissolved by the acid. This amounted to 0.35 per cent in duplicate determinations, and together with 0.06 per cent in the acid solution, or 0.41 per cent in all, may serve as a maximum figure by which to gage the action of the cold acid on the silicate or silicates in the ore. The residue was then digested for several hours with warm nitric acid of about 1.2 specific gravity until, as shown by a companion test, its action had ceased. It was then filtered, washed, and digested with 5 per cent sodium carbonate solution to dissolve the copious deposit of silica. The final residue was collected in a Gooch crucible, washed with sodium carbonate, followed by dilute nitric acid to remove all alkali, then by alcohol to prevent turbidity in the filtrate, and dried by suction of the pump. In it the water was determined at different temperatures; also its general composition.[a] From the sodium carbonate filtrate the silica was obtained by two evaporations and filtrations; also the trifling amount held by the acid solution. This latter was then fully analyzed and the complete results follow:

| | Per cent in ore. | Per cent calculated to 100. | Ratios. | |
|---|---|---|---|---|
| $SiO_2$ | 6.48 | 43.94 | 0.7275 | |
| $Al_2O_3$ | [b] 2.445 | 16.58 | 0.1622 | |
| $V_2O_3$ | [c] .965 | 6.54 | .0434 | .2426 |
| $Fe_2O_3$ | [d] .875 | 5.93 | .0370 | |
| CaO | .035 | .24 | .0043 | |
| MgO | [e] .654 | 4.43 | .1099 | .1142 |
| $K_2O$ | .546 | 3.70 | .0393 | |
| $Na_2O$ | .03 | .20 | .0037 | .0430 |
| $H_2O$ at 105° C. | [f] 1.66 | 11.26 | .9222 | |
| $H_2O$ at 300° C. | [f] .44 | 2.98 | .1655 | |
| $H_2O$ above 300° C. | [f] .62 | 4.20 | .2333 | |
| | 14.75 | 100.00 | | |

[a] $SiO_2$, 48.89; $Al_2O_3$, $Fe_2O_3$, zircon, etc., 0.44; $TiO_2$, 0.08, MgO, 0.01; $K_2O$, 0.11; $Na_2O$, 0.03; $H_2O$, 0.07; total, 49.63. [b] 2.45 and 2.44. [c] 0.93 and 1.00. [d] 0.87 and 0.88. [e] 0.652 and 0.657. [f] Determined on a separate portion of the same powdered sample. See p. 25, footnote, for data.

Also traces of titanium, manganese, and lithium.

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On the improbable assumption that the iron is to be wholly included, and regarding only the water given off above 300°, the following ratios result:

$$H_{467}\ R'_{86}\ R''_{114}\ R'''_{485}\ Si_{727}\ O_{2573};$$

which become, if the iron is excluded,

$$H_{467}\ R'_{86}\ R''_{114}\ R'''_{411}\ Si_{727}\ O_{2462}.$$

These figures, while strongly suggesting definite ratios between certain of the constituents, do not under the circumstances warrant the deduction of a formula, nor do they lead to the same conclusion as in the case of the green cementing material of the sandstone at Placerville. The phengite-muscovite ratio of that is not apparent here; yet it is not at all unlikely that a mineral like the one from Placerville is present, but contaminated with some other. In fact it would be surprising to find anything but a mixture in sandstones so thoroughly altered. The very existence of such vanadiferous transition products is itself highly interesting, and these tedious analyses were not therefore made in vain. The mud-like amorphous character of this material precludes any hope of aid from the microscope in solving the question of its homogeneity.

## SUMMARY.

The body called carnotite is probably a mixture of minerals, the exact nature of which analysis fails to reveal. Instead of being the pure uranyl-potassium vanadate, it is to a large extent made up of calcium and barium compounds. Intimately mixed with and entirely obscured by it is an amorphous substance—a silicate or mixture of silicates—containing vanadium in the trivalent state probably replacing aluminum.

The deposits of carnotite, though distributed over a wide area of country, are for the most part, if not altogether, very superficial in character and of recent origin.

The green coloring and cementing material of certain sandstones near Placerville, Colo., is a cryptocrystalline alumino-vanadio-potassium silicate resembling roscoelite, but with the percentage proportions of $Al_2O_3$ and $V_2O_3$ reversed. It constitutes over 25 per cent of portions of the sandstone, and contains nearly 13 per cent of $V_2O_3$, the latter amounting in the maximum case observed to 3.5 per cent of the sandstone.

As yet (1900) these highly vanadiferous sandstones have been found only at Placerville, where it is intended to work them for vanadium. Carnotite is associated with them in only trifling amount.

Other sandstones noticed owe their bright green color to chromium.

In yet another case where the color was dull green this was not due to either chromium or vanadium.

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# SOME ADDITIONS TO THE ALUNITE-JAROSITE GROUP OF MINERALS.

By W. F. Hillebrand and S. L. Penfield.

Two new varieties of jarosite will be described in the present paper. One is from Nevada, and was collected by Mr. H. W. Turner, of the United States Geological Survey, and sent to the Survey laboratory at Washington for identification; the other is from New Mexico, and was sent by Mr. J. H. Porter, of Denver, Colo., to the mineralogical laboratory of the Sheffield Scientific School. Except for slight differences in color the two minerals look exactly alike, each consisting of minute, isolated, tabular crystals, which, as may be seen with the microscope, are composed of combinations of a rhombohedron with largely developed basal planes. By chance it happened that the present writers discovered that they were both engaged in the investigation of compounds belonging evidently to the same group, and it was decided to bring the results together into one paper.

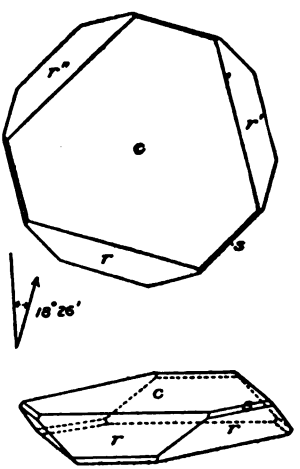






Fig. 1.—Natrojarosite.

## NATROJAROSITE.

The material collected by Mr. Turner was obtained on the east side of Soda Springs Valley, Nevada, on the road from Sodaville to the Vulcan copper mine. It consists of a glistening powder, made up of perfect crystals having the habit shown in fig. 1, although generally only one rhombohedron, *r*, is present instead of two, as shown in the figure. The largest crystals observed were 0.15 mm. wide and 0.025 mm. thick, and the general average would not be over half that size. In spite of their minuteness, however, it was possible to measure the angles of the crystals with the reflection goniometer, the chief difficulty arising not so much from their small size as from the vicinal character of the basal planes. After repeated trials a crystal was



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found having a fairly good basal plane, and from this crystal the following angles were obtained:

| | Measured. | | Measured. | Calculated. |
|---|---|---|---|---|
| $c \wedge r$, | $0001 \wedge 10\bar{1}1 = 51° 53'$ * | $c \wedge s$, | $0001 \wedge 02\bar{2}1 = 68° 42'$ | 68° 35′ |
| $c \wedge r'$, | $0001 \wedge \bar{1}101 = 51\ 53$ | $c \wedge s'$, | $0001 \wedge \bar{2}021 = 68\ 48$ | 68 35 |
| $c \wedge r''$, | $0001 \wedge 0\bar{1}11 = 52\ 26$ | $r \wedge r'$, | $10\bar{1}1 \wedge \bar{1}101 = 86\ 5$ | 85 54 |

The crystals belonged to the rhombohedral division of the hexagonal system, and the angle $c \wedge r$, 51° 53′, which is probably very nearly correct, has been assumed as fundamental, and from it the following axial ratio has been calculated:

$$c = 1.104.$$

That the axial ratio as given is very near the truth is shown by the fact that the measurements of $c \wedge s$ and $r \wedge r$ do not vary many minutes from the calculated values; while on a number of other crystals, measurement of the angle $c \wedge r$, though varying considerably, was found to be not far from 52°. The angles of $c \wedge r$ and $r \wedge r'$ of the ordinary potassium jarosite are 55° 16′ and 90° 45′, respectively.

Under the microscope the crystals exhibit normal optical properties. With a high-power lens and convergent light the thicker crystals show the dark cross and the beginnings of the first ring of the interference figure. The birefringence is negative. The color of single crystals, when seen under the microscope in transmitted light, is golden yellow. Many of the crystals show numerous brown inclusions. The color shown by a mass of the crystals is yellowish brown, and the material glistens, owing to reflections from the basal planes of the minute crystals.

The material used for the chemical analysis was the purest that could be obtained, although crystals containing the brownish inclusions just mentioned could not be avoided, and there were occasional brown ferruginous particles mixed with the crystals. The specific gravity of the material was found to be 3.18 at 30.5° C. The results of the analysis by Hillebrand are as follows:

| | | Ratio. | |
|---|---|---|---|
| $Fe_2O_3$ | 50.98 | 0.319 | 3.29 |
| $Na_2O$ [a] | 6.03 | .094 | 1.01 |
| $K_2O$ | .35 | .004 | |
| $SO_3$ | 30.96 | .387 | 4.00 |
| $H_2O$ below 105° | .12 | | |
| $H_2O$ above 105° | 11.03 | .613 | 6.33 |
| $As_2O_5$ | .20 | | |
| $SiO_2$ | .23 | | |
| CaO | .04 | | |
| | 99.94 | | |

[a] Of the soda 0.22 per cent is not extracted by hot water after full ignition of the mineral, and hence may belong to a feldspar or some other foreign mineral. Only 5.81 per cent is assumed to belong to the jarosite and used in deriving the molecular value.



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The ratio of $Fe_2O_3 : Na_2O : SO_3 : H_2O$ is evidently 3:1:4:6 as in ordinary jarosite, where the alkali is potash instead of soda. The slight excess of $Fe_2O_3$ and $H_2O$, as indicated by the ratio, is evidently due to some ferric hydroxide; probably the dark ferruginous impurities seen under the microscope are in part responsible for this, and there are also traces of some arsenate and silicate present. By attributing the excess of $Fe_2O_3$ and $H_2O$ to impurities, it is found that 94 per cent of the material analyzed may be regarded as pure natrojarosite, as indicated below:

| | After deducting impurities. | Theory for $Na_2Fe_6[OH]_{12}[SO_4]_4$. |
|---|---|---|
| $Fe_2O_3$ | 46.43 or 49.39 | 49.49 |
| $Na_2O$ | 5.81 or 6.18 | 6.39 |
| $K_2O$ | .35 or .37 | ..... |
| $SO_3$ | 30.96 or 32.94 | 32.99 |
| $H_2O$ | 10.45 or 11.12 | 11.13 |
| | 94.00 or 100.00 | 100.00 |

That 6 per cent of impurities should be present in a crystalline powder such as was analyzed is not surprising when it is taken into consideration that it would require something like 2,500,000 crystals to make one gram of material, the estimation being based on the assumption that the crystals are 0.10 mm. in axial diameter and 0.02 mm. thick, which is certainly above their average size.

Among the specimens from Cooks Peak, New Mexico, sent to the Sheffield laboratory by Mr. Porter, were some masses of a rather firmly cemented aggregate of minute crystals of a mineral of the jarosite group. The specimens are of a brownish-yellow color, and have in places the glistening appearance of a mica-schist. They also look as though they had been subjected to pressure and had been somewhat sheared. The material is rather easily crushed, and the powder, when examined with the microscope, exhibits the proprieties of the natrojarosite just described. The crystals are associated with a little limonite and quartz, and pure material for analysis could not be obtained. Only a partial analysis, therefore, was undertaken with the following results:

| | |
|---|---|
| $Fe_2O_3$ | 55.60 |
| $Na_2O$ | 4.49 |
| $K_2O$ | .77 |
| PbO | .96 |

$SO_3$ and $H_2O$ were present but not determined. The results are sufficient to indicate that the material is essentially natrojarosite.

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## PLUMBOJAROSITE.

This material is from Cooks Peak, New Mexico. It occurs as a glistening, crystalline powder and as loosely cohering masses which may easily be crushed by pressure between the fingers. The crystals are very symmetrical, and are exactly like those of natrojarosite (fig. 1), although generally only one rhombohedron, $r$, is present. On the average the crystals are a trifle smaller and noticeably thinner than those of natrojarosite. A number of crystals were measured on the reflecting goniometer, the chief difficulty arising rather from the vicinal character of the faces than from their small size. One unusually large crystal, 0.28 mm. broad and 0.015 mm. thick, was finally found, having the development shown in fig. 2, which is unusual, for generally $r$ ($10\bar{1}1$) and not $s$ ($02\bar{2}1$) is the prevailing rhombohedron. Fortunately the crystal was so taken up on a minute point of wax that the measurement of $s \wedge s$ in three rhombohedral zones was possible. The results of five measurements of $s$ $s$ over the upper and lower pole edges varied between 109° 5′ and 109° 30′, the average being 109° 16′; while six measurements over the middle edges varied between 70° 10′ and 71° 00′, the average being 70° 36′. The average of the two supplementary values gives $s \wedge s$, $2\bar{2}01 \wedge 02\bar{2}1 = 109° 20'$, which has been assumed as fundamental, and from it the following axial ratio has been calculated:

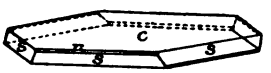


FIG. 2.—Plumbojarosite.

$$c = 1.216.$$

On the crystal from which the foregoing measurements were obtained the basal plane was vicinal and hence no reliable measurements of $c \wedge s$ could be had from it. On a number of other crystals, however, the angle of $c \wedge r$ was measured with varying results, the variation resulting from the uncertainty of the reflections from the basal planes. Four measurements of $c \wedge r$, which were recorded in the notebook as derived from the best reflections, varied between 54° 15′ and 54° 44′, the average being 54° 30′, while $c \wedge r$, $0001 \wedge 10\bar{1}1$, by calculation from the fundamental measurement, is 54° 32′. Hence it may be assumed that the axial ratio as established is reasonably exact. The calculated value of $r \wedge r$, $10\bar{1}1 \wedge \bar{1}101$, is 89° 42′.

In polarized light the crystals exhibit normal optical properties and negative birefringence. Being on the average thinner than crystals of natrojarosite, it is seldom that, with the highest powers and convergent light, even the beginning of the first ring of the uniaxial interference figure is visible. Individual crystals show under the microscope in transmitted light a golden-yellow color. A mass of crystals has the appearance of a glistening dark-brown powder, the color being decidedly darker than that of natrojarosite.

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The analysis of the mineral was made on the very best material, having a specific gravity of 3.665 at 30° C. The results are surprising, and were wholly unlooked for, since it is found that this jarosite contains lead in the place of alkalies. The results by Hillebrand are as follows:

| | I. | II. | III. | IV. | Mean. | Ratio. | |
|---|---|---|---|---|---|---|---|
| $Fe_2O_3$ | 42.36 | 42.38 | ..... | ..... | 42.37 | 0.265 | 3.15 |
| $Al_2O_3$?[a] | .12 | .08 | 0.11 | ..... | .10 | .001 | |
| PbO | 19.69 | 19.99 | 19.89 | 19.79 | 19.84 | .089 | 1.05 |
| $K_2O$ | .17 | ..... | ..... | ..... | .17 | ..... | |
| $Na_2O$ | [b].21 | ..... | ..... | ..... | [b].21 | ..... | |
| $SO_3$ | 27.05 | 27.07 | ..... | ..... | 27.06 | .338 | 4.00 |
| $H_2O$ below 105° | .02 | ..... | ..... | ..... | .02 | ..... | |
| $H_2O$ above 105° | 9.59 | 9.49 | ..... | ..... | 9.54 | .530 | 6.27 |
| $SiO_2$ | .56 | .51 | .47 | ..... | .51 | ..... | |
| CuO | .27 | .27 | ..... | ..... | .27 | ..... | |
| CaO | .05 | ..... | ..... | ..... | .05 | ..... | |
| MgO | .01 | ..... | ..... | ..... | .01 | | |
| | ..... | ..... | ..... | ..... | 100.15 | ..... | |

[a] The presence of alumina was not definitely proved. The figures here given are the differences between the several weights of the ammonia precipitates and those of the ferric iron in them, as determined by permanganate after reduction by hydrogen sulphide.
[b] Probably somewhat high.

The ratio of $Fe_2O_3 : PbO : SO_3 : H_2O$ is very close to 3 : 1 : 4 : 6, indicating that the mineral is a variety of jarosite, and the slight excess of $Fe_2O_3$, $H_2O$, and PbO + alkalies may be accounted for by assuming that slight impurities are present, partly ferric hydroxide, in part some lead salt, and perhaps a soluble silicate, as shown by the complete solubility of the silica in acids. Assuming that the ratio is exactly 3 : 1 : 4 : 6, it is found that 4.36 per cent of impurities are present, and the remaining 95.64 per cent may then be regarded as plumbojarosite, as follows:

| | Theory for $PbFe_6[OH]_{12}[SO_4]_4$. |
|---|---|
| $Fe_2O_3$ | 40.59 or 42.44 |
| PbO | 18.86 or 19.72 |
| $SO_3$ | 27.06 or 28.29 |
| $H_2O$ | 9.13 or 9.55 |
| | 95.64 or 100.00 |

Since it took probably 2,500,000 crystals of natrojarosite to make 1 gram of material, it certainly must have taken fully 4,000,000 to make a gram of plumbojarosite, for the crystals of the latter mineral, though somewhat heavier, are decidedly thinner than those of the former; hence the presence of 4.5 per cent of impurities in such a crystalline product is not to be wondered at.

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## JAROSITE AND ALUNITE.

As may be seen from the published analyses of these minerals, the alkali metal they contain is almost always potassium, though sodium is at times present. The formulas assigned to the two minerals are therefore $K_2O+3Fe_2O_3+4SO_3+6H_2O$ and $K_2O+3Al_2O_3+4SO_3+6H_2O$, which may be variously expressed, as will be indicated later.

A mineral corresponding to natrojarosite of this article, though containing a little potash, has been described by W. P. Headden[a] from the Buxton mine, Lawrence County, S. Dak. The crystals are described as scales, consisting of a combination of base and rhombohedron. The material analyzed was evidently somewhat impure, as quartz and some $As_2O_5$ are reported. As the $As_2O_5$ evidently does not belong to jarosite, the assumption may be made that some scorodite, $FeAsO_4.2H_2O$, is present, and the results of Headden's analysis may then be interpreted as follows:

| | Original analysis. | Scorodite and quartz. | Natrojarosite. | Ratio. |
|---|---|---|---|---|
| $Fe_2O_3$ | 46.27 | 1.60 | 44.67 or 50.10 | 3.13 |
| $Na_2O$ | 4.35 | ..... | 4.35 or 4.86 | |
| $K_2O$ | 1.47 | ..... | 1.47 or 1.65 | 1.04 |
| CaO | .39 | ..... | .39 or .44 | |
| $SO_3$ | 28.46 | ..... | 28.46 or 31.93 | 4.00 |
| $H_2O$ | 10.55 | .72 | 9.83 or 11.02 | 6.13 |
| $As_2O_5$ | 2.36 | 2.36 | ..... | ..... |
| Quartz | 6.10 | 6.10 | ..... | ..... |
| | 99.95 | 10.78 | 89.17 or 100.00 | ..... |

Thus, assuming the presence of 4.68 per cent of scorodite and 6.10 of quartz, and deducting them, the remainder agrees very closely with natrojarosite, giving a good ratio, very near 3:1:4:6.

Alunite containing considerable soda has been described by Whitman Cross[b] from Rosita Hills, Colorado, and by E. B. Hurlburt[c] from Red Mountain, Colorado, and analyses of both minerals show about equal percentages of $K_2O$ and $Na_2O$, or a molecular ratio of $K_2O:Na_2O=4:7$. The occurrence, therefore, of sodium in the jarosite-alunite group is in accordance with previous observations, but the case is quite different with lead. As far as the present writers are aware, this is the first instance on record where lead has been observed isomorphous with the alkali metals. It is interesting to note that the alunite from Red Mountain, Colorado, occurs as a crystalline powder, the crystals being exactly like those of natrojarosite and plumbojaro-

[a] Am. Jour. Sci., 3d ser., 46, 1893, p. 24. [b] Ibid., 41, 1891, p. 472. [c] Ibid., 48, 1894, p. 130.

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site, except that they are a trifle smaller and white, or colorless, when seen under the microscope.

From a chemical standpoint the most interesting feature of the new minerals is the light they throw upon the isomorphism of potassium, sodium, and lead. Ordinarily, even potassium and sodium are not isomorphous, as shown by the fact that their simple salts seldom crystallize in the same form. Although KCl and NaCl both crystallize in cubes, it is not certain that both salts belong to the same group of the isometric system. It has been shown, for example, by etching, that KCl crystallizes like $NH_4Cl$ in the plagihedral group of the isometric system, while the etchings produced on halite seem to indicate that it crystallizes in the normal group. Again, at Stassfurt, Germany, sylvite and halite both occur crystallized side by side upon the same hand specimen, instead of mixing as isomorphous molecules. Even in such complex molecular compounds as the feldspars, the potassium and sodium salts crystallize as orthoclase and albite, rather than as isomorphous mixtures. Lastly, potassium has a strong tendency to form alums, which is not shared by sodium. In contrast to these differences in chemical nature, we have in the jarosite-alunite group of minerals not only the alkali-metals, potassium and sodium, but, what seems still more remarkable, *lead*, playing the same rôle in the compounds, and yielding crystals which are surprisingly alike in all their physical properties. The writers can at present offer no other reason for the isomorphism in the group of minerals under consideration than that the alkalies and lead play so small a rôle, and the remaining constituents so prominent a part in the complex chemical molecules, that the latter control or dominate the crystallization by virtue of what may be called their *mass effect*.

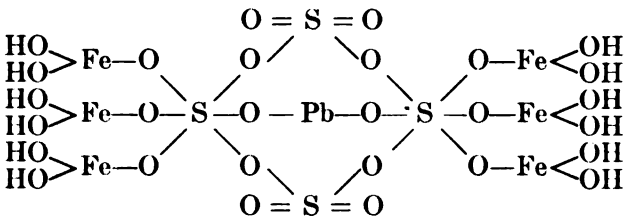
The alunite from Red Mountain, described by Hurlburt, was analyzed in the Sheffield mineralogical laboratory under the direction of one of the present writers, and it was found that water was first expelled from the compound at a rather high temperature, thus indicating that the mineral contains hydroxyl and no water of crystallization; accordingly it was shown that the seemingly complex formula of the mineral, expressed by the ration $Al_2O_3 : K_2O : SO_3 : H_2O = 3 : 1 : 4 : 6$, may be much simplified to $K[Al(OH)_2]_3[SO_4]_2$. In the light of the present investigation it now seems best to abandon the above simple formula and adopt one containing double the number of atoms, in order to make clear the isomorphism between $K_2$, $Na_2$, and Pb. The formulas of the minerals of the group would then be expressed as follows:

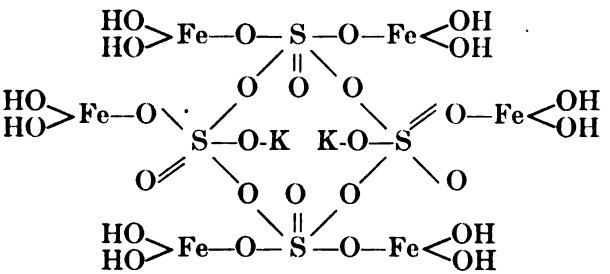
| | | |
|---|---|---|
| Alunite | $K_2[Al(OH)_2]_6[SO_4]_4$ | or $K_2Al_6[OH]_{12}[SO_4]_4$ |
| Natroalunite | $Na_2[Al(OH)_2]_6[SO_4]_4$ | or $Na_2Al_6[OH]_{12}[SO_4]_4$ |
| Jarosite | $K_2[Fe(OH)_2]_6[SO_4]_4$ | or $K_2Fe_6[OH]_{12}[SO_4]_4$ |
| Natrojarosite | $Na_2[Fe(OH)_2]_6[SO_4]_4$ | or $Na_2Fe_6[OH]_{12}[SO_4]_4$ |
| Plumbojarosite | $Pb[Fe(OH)_2]_6[SO_4]_4$ | or $PbFe_6[OH]_{12}[SO_4]_4$ |

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In the case of the lead compound one atom of lead, and in the others two atoms of either potassium or sodium, are combined in complex molecules containing fifty other atoms; hence that the complex of fifty atoms, to the right of the $K_2$, $Na_2$ and Pb in the foregoing formulas, should control or dominate crystallization by virtue of *mass effect*, and condition an isomorphism between such unlike elements as sodium, potassium, and lead is not so surprising as would at first appear.

Having adopted the double formulas, as given above, there are numerous ways of writing developed formulas, of which the following are perhaps the simplest and most satisfactory:





It is interesting to note that although $K_2$, $Na_2$ and Pb play so small a rôle in the alunite-jarosite molecules, the substitution of $Na_2$ for $K_2$ is attended by a marked variation in the angles of the crystals, greater, in fact, than is generally observed in isomorphous replacements. That alunite and jarosite containing potash would be nearly alike in their angles is expected, since crystals of corundum and hematite are surprisingly alike, as shown by the following comparison:

| | Axial length. | $r \wedge r'$ | $c \wedge r$ |
|---|---|---|---|
| | | ° ′ | ° ′ |
| Corundum, $Al_2O_3$ | 1.3630 | 93 56 | 57 34 |
| Hematite, $Fe_2O_3$ | 1.3656 | 94 00 | 57 37 |

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The relations of the minerals of the alunite-jarosite group are as follows:

| | Axial length. | $r \wedge r'$ | $c \wedge r$ | Birefringence. |
|---|---|---|---|---|
| | | ° ′ | ° ′ | |
| Alunite | 1.252 | 90 50 | 55 19½ | Positive. |
| Jarosite | 1.245 | 90 45 | 55 16 | Negative. |
| Natrojarosite | 1.104 | 85 54 | 51 53 | Do. |
| Plumbojarosite | 1.216 | 89 42 | 54 32 | Do. |

From the foregoing table it is seen that the substitution of sodium for potassium in jarosite has brought about greater variation in the angles of the crystals than the substitution of the bivalent metal lead for potassium.

The three minerals, natrojarosite, plumbojarosite, and the Na-K-alunite from Red Mountain, are very interesting when studied together as microscopic mounts, the crystals being practically alike in size and development, and illustrating very beautifully on the one hand the isomorphism of aluminum and iron, on the other the isomorphism of potassium, sodium, and lead. The three substances must have formed under like conditions, and it is believed that they are solfataric products, formed under the combined action of heat and pressure. Being difficultly soluble, they have formed, like many precipitates, as fine crystalline powders.

The three products just mentioned, when heated in closed tubes, behave alike; they suffer no change on gentle heating, but when the temperature is sufficiently high to decompose the chemical molecules, the crystals break up into fine powder or dust, which is carried along by the escaping vapors and deposited for a considerable distance along the sides of the tubes. In addition to water, $SO_2$ and $SO_3$ are copiously given off during decomposition. In the case of natrojarosite, and the same would doubtless hold true for the Na-K-alunite, it is found that after ignition one-fourth of the sulphate radicle has been retained by the alkali metal, and may be extracted by water. In the case of plumbojarosite, however, all of the sulphate radicle is expelled by ignition, doubtless because the ferric-oxide present serves to decompose any lead sulphate which might have a tendency to form. Anglesite, $PbSO_4$, when heated alone in a closed tube suffers no decomposition, but when finely triturated with limonite and heated, acid water is given off. Finely powdered natrojarosite and plumbojarosite are slowly but completely soluble in boiling hydrochloric acid. Plumbojarosite when fused with sodium carbonate on charcoal yields globules of lead and a coating of lead oxide.

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It has seemed to the writers best to designate the new compounds described in this article as natrojarosite and plumbojarosite, the names signifying their relation to a well-known species. Other members of this group will doubtless be found, and the name "natroalunite" might be employed to designate the two varieties of alunite from Colorado mentioned on page 37, where the proportion of the soda to the potash molecule is 7 : 4. It is highly probable that a series of alunite-jarosite compounds could be made artificially.

It is with pleasure that the writers acknowledge their indebtedness to Messrs. Turner and Porter for calling attention to the interesting compounds described in this article.

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# MINERALS FROM THE CLIFTON-MORENCI DISTRICT, ARIZONA.

By W. LINDGREN and W. F. HILLEBRAND.

In 1902 an examination was made of the Clifton-Morenci copper district in Arizona. Study of the collections proved the presence of several interesting minerals, a brief account of which is here given. The copper deposits at Clifton and Morenci consist partly of irregular or tabular bodies of oxidized ores in Paleozoic limestones, partly of chalcocite ores connected with fissure veins in a granite-porphyry or in the same limestones.

## CORONADITE.

On the dump of a small shaft on the west end of the Coronado vein, three-fourths of a mile west of Horseshoe shaft, fairly large amounts of a dark metallic mineral were found intimately intergrown with quartz and decomposing into limonite. The vein at this end shows no copper minerals, but is said to contain some gold, and its surface ores are reported to have been worked in an arrastre in the early days of the camp. In color this mineral is black and its structure is delicately fibrous. The hardness is about 4 and the streak black with brownish tinge.

A thin section proves it to be opaque, and in reflected light its fibrous and homogeneous structure is well brought out. It cements angular quartz grains and its secondary nature is clearly indicated. In general aspect it is not unlike psilomelane. A preliminary examination showed that it contained the oxides of lead and manganese. As it did not seem to correspond to any known mineral species, an analysis was made, after a partial mechanical separation. The results were as follows:

Long-continued efforts to procure pure material for analysis by the use of heavy solutions were not attended with success. The ultimate product of specific gravity, 5.246 at 22°, yielded on decomposition by hydrochloric acid a residue of from 6 to 7 per cent, which consisted mainly of silica, with a small amount of alumina, etc. Its presence would not have mattered much had it been quite indifferent to acids, but its partial solubility, as shown by the varying amounts undissolved on different trials, and similar varying amounts of alumina and perhaps



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other minor ingredients found in solution, renders the calculation of molecular ratios not altogether certain in all cases. The composition as found is:

| | |
|---|---|
| $MnO_2$ | [a] 56.13 |
| MnO | 6.56 |
| PbO | 26.48 |
| ZnO | .10 |
| CuO | .05 |
| $MoO_3$ | .34 |
| $Al_2O_3$ | [b] .63 |
| $Fe_2O_3$ [c] | 1.01 |
| $H_2O$ | [d] 1.03 |
| Insol. and silica | 7.22 |
| CaO, MgO, Alk., and loss | .45 |
| Total | 100.00 |

The material available did not permit the quantitative determination of the vanadium, which may be present in rather more than a mere trace, but neither it nor the phosphorus can influence materially the ratios given below. The vanadium would be effective in two ways: (1) by requiring a base for its neutralization, if existing as an acid constituent, and (2) by liberating chlorine when acted on by hydrochloric acid, and thus affecting the values found for peroxide oxygen. If the iron exists in the ferrous state, it too would affect the values found for the peroxide oxygen, and consequently for both the oxides of manganese. Assuming it to so exist and applying the proper corrections, also deducting from the lead oxide an equivalent for the molybdenum, assuming its existence as molybdate of lead, the following are the results:

| | | | |
|---|---|---|---|
| $MnO_2$ | 56.68÷ 87.0=0.6515 | | =3.00 |
| MnO | 6.11÷ 71.0= .0861 | | |
| PbO | 26.96÷222.9= .1165 | | |
| FeO | .91÷ 72.0= .0126 | 0.217 | =1.00 |
| ZnO | .10÷ 81.0= .0012 | | |
| CuO | .05÷ 79.0= .0006 | | |
| $H_2O$ | 1.03÷ 18.0= .0572 | | = .264 |

[a] Mean of 56.10 and 56.16. Total Mn as MnO from $MnSO_4$, 52.38 per cent. Peroxide oxygen, 10.31 per cent.

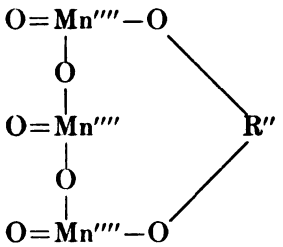
[b] With a little $TiO_2$, $P_2O_5$, and $V_2O_5$.

[c] State of oxidation not known.

[d] Nothing at 100°, only 0.14 per cent below 200°.

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If the mineral is to be regarded as anhydrous, the comparatively simple formula $R''(Mn_3O_7)''$ satisfies the above ratio, and it may be written structurally·




in which R''=Pb'' or Mn''. This is to be regarded as a saturated salt of one of the numerous possible derivatives of ortho-manganous acid that may be derived from it by removal of water, in the present case as follows:

$$3H_4MnO_4 - 5H_2O = H_2Mn_3O_7$$

An acid of the same empirical formula would result by removal of two molecules of water from three of metamanganous acid, $H_2MnO_3$.

It is probably best to rest for the present content with the above relatively simple formula and to regard the water found as due to incipient alteration. But if the water is to be considered as wholly or in part essential, and furthermore constitutional—and this may very well be the proper view to take—then the formula becomes much more complex, namely, $R_4''H_2(Mn_{12}O_{29})$, when none of the water is allotted to the foreign matter. This formula is still referable graphically to a more highly condensed manganous acid, and a number of isomers would be possible.

Such intricate formulas as this should not cause the least surprise, however unlikely they may at first appear to be. The great number of manganites in varying degrees of saturation and hydration observed in nature and prepared artificially, some of them of even greater complexity than the above, are certainly not all mixtures of only a few simply constituted molecules. A very short study of the graphic formula corresponding to the above empirical formula $R''_4H_2(Mn_{12}O_{29})$ will show what a vast number of closely related bodies are theoretically producible by hydrating the molecule step by step or by adding to or reducing the number of bivalent atoms or substituting for them those of another valence. Similar varieties in great number would be derivable from other condensed manganous acids of both higher and lower orders, and it is plain that because of the very slight differences in percentage composition between many of them it is almost as hopeless to expect analysis to reveal the exact empirical formula in the majority of cases as it is for the enormously complex albuminous

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bodies of organic chemistry. This is especially true because in so many cases the mineral manganites described are far from being homogeneous species. They are either mixtures of two or more of these closely related complex molecules or else are contaminated by foreign bodies. It is not surprising, then, that so many compounds of uncertain formula that may be regarded as salts of manganous acid have been prepared in the laboratory or are found in nature. From the known tendency of these bodies to form under laboratory conditions which may very well be repeated in their general character in nature, it is to be expected that a vast number of mineral manganites should exist, and it ought rather to excite surprise than otherwise if two or more are not formed simultaneously from the same solution. This, together with inherent difficulties of analysis, would offer a simple explanation of the fact that so few of the analyses made lead to rational formulas. If formed from solution, their original state might well be one of hydration either as regards water of crystallization or of constitution. The temperature at which the water is expelled in the present case indicates constitutional water.

Our search of the literature has not revealed a native manganite carrying a high percentage of lead, although artificial compounds have been prepared. For this reason, and because of its distinctly crystalline character, the present mineral seems worthy of a specific name. The one we propose is *coronadite*, after the famous explorer of that portion of the American continent from which the Territories of New Mexico and Arizona have been formed.

## CHALCOCITE.

The cuprous sulphide ($Cu_2S$) is very common in the Clifton district; in fact, it constitutes at present the principal valuable mineral in the ores. It occurs chiefly intergrown with pyrite, in the altered porphyry, as disseminated grains or as solid seams or veins which rarely exceed 2 or 3 feet in thickness. It is never crystallized but has ordinarily an earthy or sooty appearance and black color; scratching with a knife reveals its semisectile character and metallic luster. In a few small massive veinlets the normal metallic luster and dark-gray color appear on fractures; a fibrous or columnar structure of the mineral is known on small seams in shale from the Montezuma mine. The mineral prefers porphyry, and the great bodies of ore now worked all occur in this rock; but it is not entirely unknown from the irregular deposits in limestone generally carrying cuprite and copper carbonates. A partial analysis of massive chalcocite from the Montezuma mine, Morenci, gave 96 per cent $Cu_2S$ and 2.4 per cent $FeS_2$, the latter probably mechanically admixed.

The chalcocite is everywhere, in this district, a secondary mineral

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formed by the replacement of pyrite by means of descending solutions of cupric sulphate. The deposition of the mineral was accompanied by the formation of quartz, chalcedony, and kaolin. In the porphyry the chalcocite ore along the veins begins 100 to 200 feet below the surface and continues to a depth of 400 feet, or even more, when it is usually replaced by pyrite, chalcopyrite, and zinc blende.

## WILLEMITE.

This rare silicate of zinc ($Zn_2SiO_4$) was found by Mr. Boutwell in the form of very small grayish crystals on a fragment of garnet rock in the Modoc open cut, on the north side of Modoc Mountain. These crystals were identified by Messrs. Pirsson and Penfield, of Yale University, who state that the stout hexagonal prisms look exactly like those from the original locality at Moresnet.

## CALAMINE.

Small transparent orthorhombic crystals of calamine $(ZnOH)_2SiO_3$ were identified on a specimen of decomposed garnet rock from the Shannon mine, just above the lime quarry.

## DIOPTASE.

The silicate of copper, dioptase ($H_2CuSiO_4$) has been found at only a few localities. Very beautiful specimens, which, however, are by no means common, have long been known from the classic locality, the Kirghese Steppes, Russia, and more recently from the French Kongo State, Africa. Dioptase is seldom found in the United States, the only recorded occurrences being at the Bon Ton mines, Chase Creek, near Clifton, Ariz., noted by R. C. Hills,[a] and from near Riverside, Pinal County, Ariz., noted by W. B. Smith.[b] Well crystallized specimens of this mineral were found on an old dump of the Stevens group of mines, on the west side of Chase Creek, near Garfield Gulch. They occurred in a small chimney of chrysocolla ore in limestone, now worked out, and the locality is believed to be the same as that described by Mr. Hills. The dioptase crystals were submitted to Prof. S. L. Penfield, who remarks on them as follows:

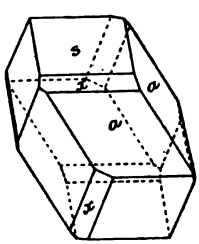


FIG. 3.—Dioptase.

The crystals, measuring from 1 to 2 mm. in diameter, occur closely grouped together, lining cavities in a brown ferruginous gangue impregnated with amorphous green material which is probably chrysocolla. The color of the dioptase is a beautiful emerald-green. The habit of the crystals, shown by the accompanying figure, is that which is most commonly observed and is especially characteristic for dioptase; prism of the second order $a$ $(11\bar{2}0)$, terminated chiefly by the rhombohedron of the first order $s$ $(02\bar{2}1)$ and with small faces of the rhombohedron of the third order $x$

[a] Am. Jour. Sci., ser. 3, vol. 23, 1882, p. 325. [b] Proc. Colorado Sci. Soc., vol. 2, 1887, p. 159.

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$(13\bar{4}1)$. As is common on this species, the prismatic faces are vicinal and the *s* and *x* faces are striated parallel to their mutual intersection edges; hence the crystals are not suited for giving accurate measurements of the angles with the reflection goniometer. One crystal was measured, and the angles of one of the rhombohedral zones, given below, are sufficiently close to the calculated values to establish the identity of the forms.

| | | Measured. | Calculated. |
|---|---|---|---|
| $a\ x$, | $11\bar{2}0$ | $13\bar{4}1 = 28°\ 55'$ | 28° 48′ |
| $s\ s'$, | $02\bar{2}1$ | $\bar{2}021 = 83°\ 48'$ | 84° 33′ |
| $s'\ a''$, | $\bar{2}021$ | $\bar{1}\bar{1}20 = 48°\ 18'$ | 47° 43′ |

By crushing some of the material, embedded in oil under a cover glass, and examination in convergent polarized light, occasional fragments were found which gave a normal uniaxial interference figure, with numerous rings indicating high birefringence. The character of the birefringence was found to be positive. Thus in all of its crystallographic and optical relations the material studied is like typical dioptase from other localities.

## CHRYSOCOLLA.

This mineral ($CuSiO_3+nH_2O$) occurs very commonly in the oxidized part of the deposits, but does not, except in some cases, constitute an important ore. On the whole, it is more abundant in the deposits in porphyry and granite than in those contained in limestone. The usual bluish green or dirty green colors and conchoidal fracture characterize it. It occurs in seams or coatings at many of the mines—abundantly in the Mammoth mine on contact fissure between porphyry and limestone; at several prospects on the Stevens group in Chase Creek near Garfield Gulch; in the Terazas fissure vein in porphyry, near Metcalf; at the Metcalf mines and many of the prospects between that place and Morenci; at the Modoc open cut, Morenci. Technical analyses of chrysocolla ore from Terazas mine by the Arizona Copper Company gave—

| | |
|---|---|
| $SiO_2$ | 31.65 |
| CuO | 34.90 |
| $H_2O$ | 26.30 |
| $Al_2O_3$ | 3.80 |
| Undetermined | 3.35 |
| | 100.00 |

Normal chrysocolla should have 34.2 per cent $SiO_2$, 45.2 per cent CuO, and 20.5 per cent $H_2O$, but the analyses show great divergency, many probably being mixtures. Moreover, what has been called chrysocolla probably includes two mineral species.

The optical characteristics of chrysocolla seem imperfectly known. Dana states that it is cryptocrystalline, while many other text-books, notably one issued in 1902 by Professor Miers, call it "amorphous."

In most cases the mineral indeed seems cryptocrystalline with bluish-gray colors of interference, but this is by no means universal.

Chrysocolla from the Modoc open cut appears as mammillary crusts

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of bluish-green color on "copper-pitch ore." The latter is isotropic and undoubtedly a distinct mineral from the chrysocolla, of brown color in varying tints, some of it opaque and showing evidence of concentric deposition. On top of the chrysocolla are thin crusts of quartz and some calcite. The chrysocolla has three different structural forms, as seen under the miscroscope: (1) The dominant mass is a cryptocrystalline to microcrystalline aggregate of particles with high birefracting index; (2) very fibrous and felted aggregates of same substance giving undulatory effects between crossed nicols and medium high colors; (3) fibrous crusts on top of 1, or also in thin layers between masses of 1, the individuals having such a remarkably parallel orientation that the aggregate of them appears almost like single crystals between crossed nicols, with black shadows sweeping across them when the table is turned. The extinction is parallel to the fibers, double refraction strong, about like augite, character negative. The same optical characteristics were repeatedly observed in thin sections of chrysocolla from Metcalf and other places. Reniform deposits were sometimes noted, the center of cryptocrystalline material coated with coarsely fibrous and highly birefringent material.

Sections from the Coronado and Metcalf mines often showed pseudomorphs of pyrite consisting of a shell of limonite with kernel of fibrous chrysocolla.

The observations of Jannettaz[a] on chrysocolla from Boleo, Baja California, Mexico, led to the same results as described above, but seem generally to have been overlooked by editors of text-books.

## COPPER-PITCH ORE.

Under this old German name is described a dark brown to black substance, sometimes dull but generally with glassy to resinous luster; hardness about 4; streak dark brown. It occurs among the products of oxidation of the deposits in limestone, as at the Detroit and Longfellow mines and Modoc open cut at Morenci, and is associated with azurite, malachite, and chrysocolla, often inclosing these minerals or replacing in branching veinlets, together with azurite, a shale-like mass, probably largely composed of kaolin. In thin section it is sometimes opaque, but often also translucent, gradual transitions obtaining in the same section, and occurs in irregular or concretionary masses, often containing small embedded crystals of a doubtful mineral, possibly a silicate of zinc. Between crossed nicols the translucent mineral always proves entirely isotropic and, except for varying depth of color and the small crystals mentioned, entirely homogeneous.

[a] Bull. Soc. Min., Paris, vol. 9, 1886, p. 211.

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A rough preliminary analysis of selected pitch black material from the Detroit mine gave

| | |
|---|---|
| CuO | 28.6 |
| ZnO | 8.4 |
| $MnO_2$ | 21.2 |
| $Fe_2O_3+Al_2O_3+P_2O_5$ | 4.0 |
| Insoluble in HCl | 22.8 |
| Ignition loss 16.3, less oxygen due to conversion of $MnO_2$ to $Mn_3O_4$. | 13.7 |
| | 98.7 |

Similar material surmounted by crusts of chrysocolla from the Modoc open cut contained much $MnO_2$, with a good deal of CuO and ZnO, and is thus evidently the same substance. Manganese is largely but not certainly wholly present as $MnO_2$. The insoluble portion consists of silica, is wholly separated by acid without need of evaporation, and is nearly all soluble in dilute potassium hydroxide. It is not possible to say whether silica is in combination or as opal, but it can not be present in any other form.

Most of these copper-pitch ores, known from many districts, have been described as impure chrysocolla. As shown by the optical characteristics, they are not, however, a mixture, and they certainly do not contain any chrysocolla, the characteristics of which are very different. They probably represent a series of closely related compounds, the chemistry of which has not yet been fully elucidated. Prof. G. A. Koenig[a] describes a similar mineral with the same isotropic character from Bisbee, and names it melanochalcite. Its composition is different, since it contains

| | |
|---|---|
| CuO | 76.88 |
| $SiO_2$ | 7.80 |
| $CO_2$ | 7.17 |
| $H_2O$ | 7.71 |
| ZnO | .41 |
| $FeS_2$ | .07 |
| | 100.04 |

Professor Koenig considers it most probably a basic salt of an orthosilico-carbonic acid. No carbon dioxide was found in the Morenci minerals. In conclusion it would seem that the chemistry of these copper-pitch ores would bear further examination.

## MORENCITE.

In a lime shale on the intermediate level of the Arizona Central mine, Morenci, 200 feet below the surface, brownish or greenish spreading masses were found, containing brownish yellow, silky fibrous seams. The inclosing material consists largely of the same material

[a] Am. Jour. Sci., ser. 4, vol. 14, Dec., 1902, p. 404.



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as the seams, but impure and mixed with a little chlorite and pyrite. The whole bears evidence of being a product of oxidation of some contact metamorphic mineral.

The fibrous mineral on the seams forms a felted aggregate as seen under the microscope, but it is well individualized and contains few impurities except a little pyrite and chlorite. The minute fibers are brownish yellow and slightly pleochroic, being darker when parallel to the principal section (opposite the behavior of biotite); the birefringence is strong and extinction strictly parallel to the fibers. No mineral corresponding to this has been described, but, although its individual character is beyond doubt, the analysis does not lead to a satisfactory formula. The material for the analysis was picked out carefully under the lens and examined under the microscope it proved satisfactorily pure.

The analysis afforded the results of the first column of figures below. In deducing the molecular ratios of the second column there has been deducted sufficient lime to form apatite with the phosphoric oxide.

| | | Molecular ratios. | |
|---|---|---|---|
| $SiO_2$ | 45.74 | 757 | = 10.71 or 11 |
| $TiO_2$ | trace | . | |
| $Al_2O_3$ | 1.98 | 019 | 205 = 2.90 or 3 |
| $Fe_2O_3$ | 29.68 | 186 | |
| FeO | .83 | 011 | 141 = 2.00 or 2 |
| MnO | trace | | |
| CaO | 1.61 | 027 | |
| MgO | 3.99 | 100 | |
| $K_2O$ | .20 | 002 | |
| $Na_2O$ | .10 | 001 | |
| $H_2O$ 105° | 8.84 | 491 | = 6.96 or 7 |
| $H_2O$ 150° | .12 | 282 | = 3.99 or 4 |
| $H_2O$ below redness | 4.27 | | |
| $H_2O$ redness | .69 | | |
| CuO | little | | |
| $FeS_2$ | .66 | | |
| $P_2O_5$ | .18 | | |
| | 98.89 | | |

It would seem from the temperatures at which the water is driven off that this must exist in two conditions, and that four-elevenths of it must be held more securely than the remaining seven-elevenths. The attempt to account for four molecules of water as constitutional, however, led to no simple or seemingly probable formula, whereas if all water is excluded the ratio is that of a metasilicate—$R''_2R'''_6(SiO_3)''_{11}$. On the other hand, to include the whole of the water as essential to the silicate molecule, for which there is little ground in

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view of the ease with which most of it is expelled, leads to an orthosilicate ratio—$R'_{22}R''_2R'''_6(SiO_4)''''_{11}$.

On the whole, considering also the bad summation of the analysis, it is more rational to regard the mineral as a hydration product of an original metasilicate molecule than to attempt to construct a complex formula which could have but a very doubtful value. As the mineral is not a mixture, but is optically well individualized, we have, after some hesitation, thought best to designate it by the name *morencite*, derived from the locality in which it was found.

## LIBETHENITE.

This hydrous, basic phosphate of copper ($H_2Cu_4P_2O_{10}$) was found 30 feet below the adit level of the Coronado lode, in the main shoot. It is a matter of interest to record its occurrence, for this rare mineral has never before been noted in the United States. It occurs in small crystals, less than 1 mm. in length, deposited in cavities and seams in a quartzite gangue. The mineral was identified by Prof. S. L. Penfield, who also kindly measured and figured the crystals. Professor Penfield describes the occurrence as follows:

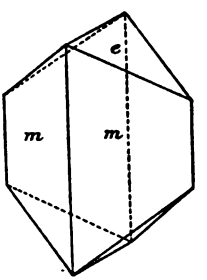


FIG. 4.—Libethenite.

The only associated minerals are occasional clusters of minute quartz crystals and small tufts of radiated malachite needles. The color of the libethenite varies from light to dark olive-green, depending upon the size of the crystals. The habit of the crystals, as shown by the accompanying illustration, is a combination of the prism $m$ (110) and brachydome $e$ (011), which is exactly like that commonly observed on libethenite from foreign localities. On an occasional crystal the brachypinacoid $b$ (010) was also observed. Although the crystals are brilliant, the faces are generally vicinal and give uncertain or multiple reflections of the goniometer signal. The best reflections were obtained from the faces of the dome $e$, and three measurements of $e \quad e'$, $011 \quad 0\bar{1}1$ gave 69° 52′, 70° 18′, and 70° 14′. The last measurement, obtained from the best reflections, is close to the value, 70° 8′, obtained by Rose. The best measurements of the prismatic angle gave $m \wedge m''$, $110 \wedge 1\bar{1}0 = 87°\ 11'$, which, considering the vicinal character of the prismatic faces, is reasonably close to the value of Rose, 87° 40′, as given in Dana's Mineralogy. A small crystal resting on a prismatic face, when examined in convergent polarized light, showed an optical axis nearly in the center of the field, with the dark bar running at right angles to the vertical axis, thus indicating that the optical axes are in the plane of the base, as determined by Des Cloizeaux. The presence of copper, water, and phosphoric anhydride was determined by chemical tests.

A more detailed search would probably reveal small quantities of phosphates from other mines near Morenci. They are certainly not abundant.

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## BROCHANTITE.

This basic sulphate of copper ($H_6Cu_4SO_{10}$) is usually supposed to be one of the rarer minerals. It was, however, discovered at a few places near Metcalf and Morenci, in well-developed crystals, and this led to a systematic microscopic examination of the green ores, hitherto supposed to be malachite. The result was surprising, as the mineral was proved to be of extremely common occurrence, mostly intergrown with malachite, which had effectively masked its presence. It is believed that a careful examination of many so-called malachites from other districts will disclose the overlooked importance of brochantite as a copper ore.

Brochantite is frequently crystallized in the short but stout rhombic prisms combined with dome and brachypinacoid characteristic of the species. Needle-shaped and flat crystals are more rare. The crystals are usually of small size and frequently microscopic. It occurs as lighter or darker emerald-green crusts on limonite or sericitized porphyry from the red ore body in the Shannon mine, from the Metcalf mines and many other places; as fine-grained aggregates in altered porphyry at the Shannon mine, near the surface, constituting valuable ore with as much as 30 per cent copper; from croppings of the King vein, filling seams and coating porphyry fragments as flat pieces or even foils with almost pearly luster; from the croppings of the Copper Queen mine between Morenci and Metcalf, here as flat stellar aggregates of bluish green foils; at many places near Morenci, as, for instance, Copper Mountain and Montezuma mines, at the latter locality replacing chalcocite. It would probably not be found absent from any mine in the district containing oxidized copper ores. Malachite often develops later than the brochantite.

On the whole, the mineral is most abundant in fissure veins in porphyry, though also occurring in the irregular deposits in limestone.

Brochantite has an excellent cleavage parallel to the brachypinacoid. The macropinacoid is the axial plane and the acute bisectrix is seen emerging in cleavage foils. Pleochroism very slight. Birefringence much lower than malachite, about equal to that of augite. This, as well as the absence of twins, distinguishes brochantite from malachite. The reaction for sulphuric acid is of course a valuable aid.

## SPANGOLITE.

This peculiar mineral ($H_{18}Cu_6AlClSO_{19}$), essentially a highly basic chloro-sulphate of copper and aluminum, was discovered and described by Prof. S. L. Penfield[a] about fifteen years ago. The specimen came from some point within 200 miles of Tombstone, Ariz., and probably

[a] Am. Jour. Sci., ser. 3, 1890, vol. 39, pp. 370–378.

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from one of the great copper camps of the Territory. Somewhat later it was identified by Prof. H. A. Miers on two specimens from Cornwall, England, but the American locality has not yet been found. It is, therefore, a matter of interest to record its discovery on some specimens from the Metcalf mine of the Arizona Copper Company, taken from the workings in the great open cut not more than 100 feet below the surface. These specimens consist of white sericitized granite-porphyry, in part silicified, and traversed by veinlets and irregular masses of cuprite; the cuprite contains native copper and is covered by crusts of malachite, brochantite, and chrysocolla. A soft and scaly bluish-green coating on the chrysocolla proved to consist of microscopical hexagonal crystals or cleavage foils, remaining dark between crossed nicols. The mineral was identified as spangolite, a determination in which Professor Penfield concurred. No measurable crystals were found, and the mineral is very inconspicuous. It is difficult, if not impossible, to obtain material entirely free from other minerals.

Selected bluish flakes from this specimen gave tests for water, and the sulphate and chlorine ions, besides copper. There was too little of this pure material to permit of a test for alumina, but the mixed copper minerals composing the greater part of the specimen showed the presence of this body. It seems therefore probable on these grounds alone that the bluish flakes are spangolite. Vanadium, phosphorus, and arsenic are absent.

The closed-tube reactions of the mixed copper minerals are very striking. Water is given off first. Then appears suddenly a white sublimate ($AlCl_3$?) near the assay, which seems to form or at once change to minute colorless drops. This deposit can be driven slowly up the tube, followed at its lower, sharply defined edge by dark yellow-brown drops ($CuCl_2$?), which on cooling solidify to greenish crystalline aggregates, and the part of the tube between them and the assay shows under the lense delicate feathery crystallizations like frost markings on window panes. Down in the flame the glass becomes colored red ($Cu_2O$?) and in parts yellow. On charcoal the blowpipe flame is colored azure blue and at the same time green.

In order to compare the above closed-tube behavior with that of undoubted spangolite, a small fragment of the latter, offered by Professor Penfield, was tested. It gave water and then a white sublimate like the one above mentioned, followed by a dark olive-brown liquid, which on cooling passed through lighter shades of color and solidified as a bright green ring. In general this behavior is very like that of the mixture under examination from Clifton.

## GERHARDTITE.

The cliffs of granite-porphyry in the deeply eroded Chase Creek Canyon at Metcalf in many places show a conspicuous and extensive bright green coating of some copper mineral, which, no doubt, is

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formed by the trickling of atmospheric waters over and through rocks containing a small percentage of copper. This is not surprising, for porphyry in this vicinity is altered throughout by quartz cementation and disseminated cupriferous pyrite. This "green paint," as it is frequently called, is not soluble in water, and more closely examined consists of small dark-green, roughly mammillary forms, coating the rock to a thickness of a few millimeters. Examination by the microscope fails to reveal any recognizable mineral in the cryptocrystalline mass.

Chemical examination led to the interesting result that the copper minerals present consist of a nitrate and a chloride, neither of which has been found elsewhere in the mines of the district. Detrital grains and some silica seem associated with these compounds. The nitrogen seems difficult to account for in the absence or scarcity of animal substances which might have yielded it. Possibly it is contained in the porphyry.

The closed-tube reactions of the copper minerals forming the mixture on this specimen are as striking in their way as those of the mixture containing spangolite, described elsewhere. Water first appears, then brownish nitrous vapors, followed by a sublimate which is not very volatile, becomes black on further heating but on cooling yellow-brown. The glass at the bottom of the tube is often yellow-brown when cold. After some hours the sublimate nearly disappears or becomes greenish from absorption of water. If the water which condenses in the upper part of the tube on first applying heat is driven out by the flame, and the mouth of the tube is held in the flame, this is colored deep green by a volatile copper compound (chloride?). On charcoal the flame is azure blue and at the same time green. Vanadium is absent.

The mixture contains presumably the basic nitrate gerhardtite ($H_6Cu_4N_2O_{13}$) and a chloride which is perhaps atacamite. Spangolite, the chloride, can hardly be present, for the slight amount of $SO_3$ shown by test does not seem sufficient to account for the large amount of chloride.

The only place from which gerhardtite has previously been identified is at Jerome mines in the central part of Arizona, associated with cuprite and malachite. It was discovered there by Messrs. H. L. Wells and S. L. Penfield.

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# TWO TELLURIUM MINERALS FROM COLORADO.

By W. F. HILLEBRAND.

## 1. EMMONSITE (?) FROM A NEW LOCALITY.

Messrs. F. L. Ransome and Waldemar Lindgren, of the Geological Survey, collected, in the W. P. H. mine at Cripple Creek, a green mineral which has been observed in other mines there, and which on examination in the laboratory showed close resemblance to the emmonsite described by the writer nearly twenty years ago.[a] It differed from it, however, in outward appearance by assuming mammillary forms instead of crystalline plates. In its optical properties, so far as they were determinable, there is perhaps no positive disagreement with those reported for emmonsite. Mr. W. T. Schaller reports as follows:

> There are two cleavages, one parallel to $b(010)$ and another parallel to a form in the orthozone. Axial plane parallel to $b(010)$. $Bx_a$ perpendicular to a cleavage face in the orthozone. The extinction on the clinopinacoid is inclined 25° to 30° to the vertical axis. 2E is approximately 40°. Double refraction medium, and the mineral nonpleochroic.

The gangue in which the specimens were found is granite and schist, close to their contact with a porphyritic breccia, in a vein pocket, at a distance of about 150 feet from the surface. Associated with it was very rich native gold ore and also tellurite, though neither of these was apparent on the few specimens that came to the laboratory.

Like emmonsite, the mineral melts at a low heat to a red-brown liquid, but, unlike it, gives on stronger heating only tellurous oxide with no trace of selenium or selenious oxide. Analysis confirmed the absence of selenium. Its density, too, differs from that of emmonsite, if the determinations in both cases on scanty material are to be depended on. After allowing for gangue, the original emmonsite was judged to have a density of at least 5, while that of the present mineral is but little above 4.53, after allowing for 24.44 per cent of gangue, consisting mainly of quartz, and to which the specific gravity of quartz was assigned.

In its appearance the present mineral would seem to resemble durdenite more than emmonsite, but the marked difference in water

[a] Proc. Colorado Sci. Soc., vol. 2, p. 20, 1885.



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content differentiates it sharply from that mineral, durdenite yielding over 10 per cent.

After deducting 22.44 per cent of gangue containing over 90 per cent of silica, three portions of from 0.15 to 0.20 gram net weight each gave the following results:

| | 1. | 2. | 3. | Mean. | Ratios. |
|---|---|---|---|---|---|
| $TeO_2$ | 70.83 | 71.80 | 70.20 | 70.71 | 3.16 |
| $Fe_2O_3$ | 22.67 | 22.81 | 22.79 | 22.76 | 1.00 |
| $H_2O$ at 100° | 4.68 | 4.82 | .21 | .21 | |
| $H_2O$ above 100° | | | | 4.54 | 1.77 |
| $P_2O_5$ | | .34 | | .34 | |
| $Al_2O_3$ | | .58 | .54 | .56 | |
| $SiO_2$, etc.[a] | | | | .88 | |
| | | | | 100.00 | |

[a] Includes alkalies, traces of magnesia and gold, and a small amount of a metal or metals precipitable by hydrogen sulphide whose identity could not be established.

Allowing the alumina to offset the $P_2O_5$, though it may belong to a soluble silicate or to the tellurite, and a small portion of iron be demanded for the $P_2O_5$, the ratios given in the final column result. They are as unsatisfactory as those afforded by the original emmonsite, which were for $Fe_2O_3$ to $TeO_2$, 1:3.65 in the original description and 1:3.75:1.82 for $Fe_2O_3$:$TeO_2$:$H_2O$ if the supplementary determinations in Am. Jour. Sci., vol. 40, p. 81, 1899, are accepted. The presence of tellurite in association with the green mineral suggests a possible explanation of the failure to obtain a simple ratio, though such contamination was not noted in the material analyzed nor on the neighboring gangue. If this explanation is correct, however, the variation from the original emmonsite ratio becomes still more marked. Provisionally, the mineral may be regarded as emmonsite.

The above results are given in some detail, notwithstanding their inconclusiveness, because of the importance of accumulating data regarding the as yet small but interesting group of ferric tellurites, and inciting collectors and mining men to careful search for and preservation of further material for more extended study.

Thus far emmonsite, durdenite, and an unnamed mineral from Cripple Creek, described by Knight in Proc. Colorado Sci. Soc., vol. 5, p. 66, and affording likewise unsatisfactory ratios, comprise the list of natural ferric tellurites, the formula of no one of which can be regarded as established beyond question.

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## 2. TETRADYMITE.

Specimens received in the Survey laboratory from Mr. H. B. Trader and said to come from some locality near Whitehorn, Fremont County, proved to be tetradymite. They showed the mineral in masses of considerable size, which, although manifesting the eminent cleavage of tetradymite, were devoid of distinct evidences of crystal form. The specific gravity at 20° C. was 7.816. Analysis afforded the following results:

| | 1. | 2. | 3. | Mean. | Atomic ratio. |
|---|---|---|---|---|---|
| Bi | 52.00 | 52.30 | 52.13 | 52.14 | 0.2498 =2.0 |
| Te | 46.62 | 46.82 | | 46.62 | .3651 |
| Se | [a].20 | | | .20 | .0025 =2.98 |
| S | .13 | .14 | | .14 | .0044 |
| $Fe_2O_3$ | .22 | | | .22 | |
| Insoluble | .15 | | | .15 | |
| | | | | 99.47 | |

[a] Approximate.

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# NOTES ON LAWSONITE.

By W. T. SCHALLER and W. F. HILLEBRAND.

Crystals of lawsonite are very simple in their combinations, the common forms being the prism, base, and brachydome. Two habits occur—tabular crystals with {001} and {110} and crystals with the forms {110} and {011}. The brachypinacoid and the brachydome {041} also occur. A large number of crystals from the typical locality in Marin County, Cal., were collected by the writer and carefully examined with a hand lens for any additional forms. Only two new forms were determined.

The forms observed on the six crystals measured are:

| | |
|---|---|
| $c=0 \quad =001$ | $d=01=011$ |
| $b=0\infty =010$ | $e=04=041$ |
| $m=\infty \quad =110$ | $r=\ 2=221$ |
| | $s=\ 3=331$ |

The angles measured, with those calculated for these forms, are quoted in the table following:

| No. | Letter. | Symbol. | | Measured. | | | | Calculated. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Gdt. | Miller. | $\phi$. | | $\rho$. | | $\phi$. | | $\rho$. | |
| | | | | ° | ′ | ° | ′ | ° | ′ | ° | ′ |
| 1 | $c$ | 0 | 001 | .. | .. | 0 | 02 | .. | .. | 0 | 00 |
| 2 | $b$ | $0\infty$ | 010 | 0 | 00 | 90 | 00 | 0 | 00 | 90 | 00 |
| 3 | $m$ | $\infty$ | 110 | 56 | 22 | 90 | 00 | 56 | 22 | 90 | 00 |
| 4 | $d$ | 01 | 011 | 0 | 09 | 36 | 36 | 0 | 00 | 36 | 27 |
| 5 | $e$ | 04 | 041 | 0 | 00 | 71 | 18 | 0 | 00 | 71 | 18 |
| 6 | $r$ | 2 | 221 | 56 | 27 | 69 | 10 | 56 | 22 | 69 | 27 |
| 7 | $s$ | 3 | 331 | 56 | 22 | 76 | 21 | 56 | 22 | 75 | 58 |



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The new pyramid $r=2=\{221\}$ is present on two crystals, the faces giving good reflections. Fig. 1 shows one crystal on which this form occurs.

The new pyramid $s=3=\{331\}$ is present on only one crystal and but one face of the form occurs. The relative size of the face is about the same as that of the preceding pyramid. The reflection was fair.

The brachydomes are usually deeply striated, rendering it difficult to determine with certainty any domes present. On two crystals reflections were obtained from two faces, measurements of which agree with the angles calculated for the form $\{034\}$. The form is rather uncertain and is not included with the others.

| Measured. | | | Calculated. | |
|---|---|---|---|---|
| $\phi$ | $\rho$ | | $\phi$ | $\rho$ |
| 0° 23′ | 28° 07′ | — 14′ | 0° 00′ | 28° 59′ |
| 0° 00′ | 28° 07′ | | | |

The combinations observed on the crystals measured are shown in the following table:

| Cryst. No. | c | b | m | d | e | r | s |
|---|---|---|---|---|---|---|---|
| 1 | .. | .. | m | d | .. | r | .. |
| 2 | .. | b | m | d | .. | .. | s |
| 3 | .. | .. | m | d | .. | r | .. |
| 4 | c | b | m | d | e | .. | .. |
| 5 | .. | b | m | d | .. | .. | .. |
| 6 | c | .. | m | d | e | .. | .. |

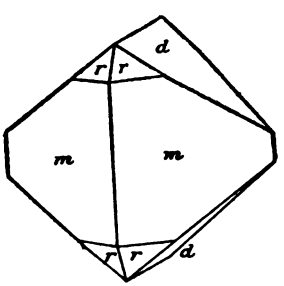



FIG. 5.—Lawsonite.

The following table is a calculation of the two new forms corresponding to the tables given in Goldschmidt's Winkeltabellen.

| No. | Letter. | Symbol. | Miller. | $\phi$. | $\rho$. | $\xi_0$. | $\eta_0$. | $\xi$. | $\eta$. | $\frac{x}{(x:y)}$ (Prism). | $y$. | $d = tg\ \rho$. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | | | |
| 6 | r | 2 | 221 | 56 22 | 69 27 | 65 45 | 55 54 | 51 13 | 31 14 | 2.2204 | 1.4770 | 2.6667 |
| 7 | s | 3 | 331 | 56 22 | 75 58 | 73 17 | 65 42 | 53 53 | 32 30 | 3.3306 | 2.2155 | 4.0001 |

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Material carefully purified by the Thoulet solution followed by repeated electromagnetic extraction, and having then a specific gravity of 3.121 at 25°, gave the following results on analysis:[a]

| | | Molecular ratio. | Calculated for the formula $H_4CaAl_2Si_2O_{10}$. |
|---|---|---|---|
| $SiO_2$ | 38.45 | 1.98 | 38.34 |
| $TiO_2$ | .38 | | |
| $Al_2O_3$ | 31.35 | .97 | 32.44 |
| $Fe_2O_3$ | .86 | | |
| FeO | .10 | 1.00 | 17.80 |
| MnO | faint tr. | | |
| CaO | 17.52 | | |
| MgO | .17 | | |
| $K_2O$ | .23 | | |
| $Na_2O$ | .06 | | |
| $H_2O$ (ignition) | 11.21 | 1.95 | 11.42 |
| Total | 100.33 | | 100.00 |

Titanium is not considered in the ratio because probably present as an inclusion of rutile or titanite. If the latter, the ratio would perhaps approximate still more closely to the theoretical than it does. The agreement with the formula deduced by Ransome and Palache from their rather widely differing analyses is very satisfactory. The behavior of the mineral before the blowpipe is somewhat different from that given by those authors, or rather their statement needs amplification. On first applying the flame a splinter appears to fuse easily, as stated, and there is formed a blebby glass, or on larger splinters a porous sinter, but this fusing is only momentary, and it requires the highest heat attainable, under which the fragment emits quite an intense light, to produce a further softening and rounding of the edges. If a rather large splinter is held in the flame of the blowpipe, or in a small flame of a blast lamp, a very sudden and marked exfoliation is observed, but even the extruded points and edges do not fuse completely in the highest attainable heat. The semifused surface, however, appears dark on cooling, sometimes nearly black where the heat was most intense. In producing this exfoliation, if care is taken to apply the flame but for a moment, it has been noticed that a singularly shaped excrescence may shoot out from a point of the surface.

[a] Concerning this purified material, Doctor Ransome reports as follows:

"I should say the material is as pure as it is possible to get it. The grains are all lawsonite, but vary in individual purity. Some are perfectly clear. Others have minute inclusions, which appear in most cases to be solid particles but are too minute for identification. One of them, however, was suggestive of rutile. Some of the grains are slightly clouded with a yellowish stain which the microscope is unable to resolve into distinct particles. There are apparently a few fluid inclusions also."

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# THE COMPOSITION OF YTTRIALITE, WITH A CRITICISM OF THE FORMULA ASSIGNED TO THALÉNITE.

By W. F. HILLEBRAND.

In a paper describing the new yttrium silicate thalénite,[a] the author, C. Benedicks, casts doubt on the formula assigned by Hidden and Mackintosh[b] to their mineral yttrialite from Llano County, Tex., for which they deduced the formula $R_2O_3 2SiO_2$ or $R_2Si_2O_7$, in which $R_2O_3$ includes the sesquioxide equivalents of very considerable percentages of monoxides and dioxides. Benedicks would assign yttrialite to a group of which rowlandite is the prototype and to which he believes thalénite and kainosite belong, these being either plain basic salts of $H_6Si_2O_7$ of the type $R''R'''_4Si_4O_{15}$ or derivatives in which the fifteenth oxygen atom is replaced by its equivalent in fluorine (rowlandite) or $CO_2$ (kainosite), as shown below.

$$\left.\begin{matrix} Y\equiv Si_2O_7=Y \\ H_2< \\ Y\equiv Si_2O_7=Y \end{matrix}\right\rangle O \qquad \text{Thalénite.}$$

$$\left.\begin{matrix} Y\equiv Si_2O_7=Y \\ Fe< \\ Y\equiv Si_2O_7=Y \end{matrix}\right\rangle O \qquad \text{Yttrialite.}$$

$$\begin{matrix} Y\equiv Si_2O_7=Y-Fl \\ Fe< \\ Y\equiv Si_2O_7=Y-Fl \end{matrix} \qquad \text{Rowlandite.}$$

$$\left.\begin{matrix} Ca=Si_2O_7=Y \\ H_4< \\ Ca=Si_2O_7=Y \end{matrix}\right\rangle CO_2 \qquad \text{Kainosite.}$$

Benedicks says:

Dem Yttrialit, von Hidden and Mackintosh beschrieben, sollte die Formel $R_2O_3$, $2SiO_2$ zukommen, worin R hauptsächlich Ytter- und Thorerde ist. Dabei wird aber ca. 4% Eisenoxydul in der Analyse vernachlässigt. Wird dies nebst etwas Kalk und Bleioxyd mitgerechnet, so bekommt man die Formel $Fe''O$, $2R_2O_3$, $4SiO_2$, analog mit der des Thalénits, welche besser die Zusammensetzung des Yttrialits wiedergibt, obgleich die Ubereinstimmung gar nicht gut ist.

[a] Bull. Geol. Inst. Upsala, 4, 1898, 1. [b] Am. Jour. Sci., ser. 3, vol. 38, 1889, p. 477.



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It is, however, not true that Hidden and Mackintosh neglected to take account of the ferrous iron, etc., of their analysis. It was regarded in the derivation of their empirical formula $R_2Si_2O_7$. How wholly unwarranted was the substitution by Benedicks of his formula for yttrialite is shown by the molecular ratio for $RO:R_2O_3:SiO_2$, which he gives as 1:2:4 instead of 1:3.25:7.42, as calculated by me from Mackintosh's figures, wherein for a sound reason I have converted his $UO_3$ into $UO_2$, thus throwing it with the $ThO_2$, where it naturally belongs. The agreement is indeed "gar nicht gut."

Benedicks has made the grave mistake of counting Mackintosh's monoxide bases a second time, thus making a basic salt $R''R'''_4Si_4O_{15}$ instead of the normal one $R'''_4Si_4O_{14}$, to which Mackintosh's results closely conform.

## DISCUSSION OF BENEDICKS'S FORMULA FOR THALÉNITE.

Moreover, in the light of the data furnished by Benedicks himself it can not be admitted that the formula $H_2Y_4Si_4O_{15}$ for thalénite is established.

Water was determined by him according to Penfield's method,[a] but without any hint as to the particular modification employed. If, as seems probable, the water expelled from the mineral was caused to recondense in the cooler part of the ignition tube, the latter being then weighed, and again after driving the condensed water out, two serious sources of error have to be considered: (1) The $CO_2$ present in the mineral, which would count in part as water unless a very careful correction was made, as provided for by Penfield. No mention is made by Benedicks of any such correction. (2) Nitrogen and helium are said to comprise 1.4 per cent of the mineral by weight. If so, these would introduce an error in the above water determination of contrary sign to that due to $CO_2$, and if the proportion of helium were large this error might be of very considerable magnitude.

In an appendix to his paper Benedicks gives an analysis of what he considers to be a very pure form of thalénite. He makes no comparison of this with his earlier analysis, nor does he deduce a molecular ratio, which I find to be 1:2.6:5.15, or 1:3.03:6.02 if small amounts of lime, magnesia, and soda are neglected, instead of 1:2:4, as required by his formula. There being no $CO_2$ in this purer material, the value for water (if determined as above surmised) may be supposed to be affected only by the error due to nitrogen and helium. It will be seen that the neglect to regard lime, magnesia, and soda in his second analysis affects the ratio very seriously. This neglect may be justified in figuring on his first analysis because of an approximate balancing by $CO_2$, but it would be by no means so in the other, in spite of the very satisfactory ratio obtained and leading to the empirical formula

[a] Am. Jour. Sci., ser. 3, vol. 48, 1894, p. 31.

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$R''R'''_4Si_4O_{22}$, which is susceptible of a variety of interpretations. It may represent a basic salt of diorthosilicic acid $R''R'''_5(R'''O)'(Si_2O_7)_3$ or of metasilicic acid $R''R'''_2(R'''O)'_4(SiO_3)_6$, or possibly even of other acids.

Finally, if the values for nitrogen and helium are really anywhere near so great as given, an additional argument against the validity of his formula is furnished. For in the light of Kohlschütter's recent researches[a] and my own less conclusive work of a much earlier date,[b] it is in the highest degree probable that nitrogen and helium are not occluded in uraninite and other minerals, but are in chemical combination. Now, if this is so, in a mineral containing as much as 1.4 per cent of nitrogen by weight, this must, quite irrespective of its form of combination, play so important a rôle in the molecule as to utterly invalidate any formula based on calculations from which it is omitted. If the above percentage is made up in large part of helium, its effect, because of its low atomic weight, must be vastly greater than that of nitrogen.

Until light is thrown on the nature of the combinations these two gases form in minerals, no very positive conclusions can be reached as to the formulas to be assigned to those minerals which contain them in more than traces.

## CHEMICAL INVESTIGATION OF YTTRIALITE.

At the earnest request of Mr. W. E. Hidden, the discoverer of yttrialite, I undertook to reanalyze the mineral in order if possible to settle definitely the question of its composition. This seemed especially desirable since a large quantity of very fine material was available.

The appearance and behavior of the mineral agreed in all respects except one with those of the original description.[c] It is there stated that the strongly ignited mineral is insoluble in acid. This is a mistake, for when powdered its solubility in hydrochloric acid is even then perfect, although not rapid.

Careful examination of thin sections under the microscope showed a condition that augured ill for decisive analytical results despite the apparently fine quality of the large specimens. Distinctly foreign mineral fragments were as good as absent except for insignificant coatings of a white alteration product, presumably a carbonate, but considerable shading was apparent in the slides, indicative of alteration or intimate contamination in the mass of the mineral itself. However, after treatment with hot dilute hydrochloric acid (whereby much yttrialite was dissolved) followed by dilute sodium carbonate, the

[a] Ann. der Chem., 317, 1901, p. 158.
[b] Bull. U. S. Geol. Survey No. 78, 1891, pp. 76–78.
[c] Am. Jour. Sci., ser. 3, vol. 38, 1889, p. 477,

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clear glassy residue appeared to be improved in appearance and the specific gravity of two samples, each composed of small grains uniform in size for each sample, had risen from 4.596 and 4.590 to 4.654 at 23½° C. and 4.646 at 26° C., respectively. The two sizes were then mixed, giving one sample of about 4.65 sp. gr. at 25° C. That of the unpurified material analyzed by Mackintosh was 4.575.

Qualitative tests showed the absence of zirconium, glucinum, and aluminum and the presence of a little more than a trace of fluorine, of a very little carbon dioxide, besides some other gases which were set free by treatment with acids and by fusion with an alkali carbonate.

Silica was separated by two evaporations with hydrochloric acid; lead was then thrown out by hydrogen sulphide.

The earths when finally collected together free from all iron, manganese, uranium, titanium, phosphorus, calcium, and magnesium, were ignited and weighed. No filtrate from a precipitate of earth oxalates was ever regarded as free from earths till after evaporating, igniting, and retesting. This is a needed precaution in all similar analyses.

The combined earths were dissolved in nitric acid and evaporated to dryness. A saturated solution of potassium sulphate was poured upon the dry mass, which wholly dissolved but almost at once began to deposit double sulphates. Solid potassium sulphate was then added in crystals. After twenty-four hours the precipitate was collected on a filter and washed with the precipitant solution. Twice was this precipitation repeated after first dissolving the double salts in acid, precipitating by potassium hydroxide, washing, redissolving in nitric acid, and evaporating. Then only was the extraction of the yttrium-erbium group practically complete. From the combined filtrates the soluble earths were thrown out, reconverted into nitrates, and again treated with potassium sulphate, whereby a little further insoluble matter was obtained. Yttrium-erbium oxides obtained from the oxalates gave a light-colored mixture of 265.6 Mol. W. (108.8 At. W.), which furnished a pink nitrate solution showing the erbium absorption bands strongly marked, with very faint indications of the strongest band of the didymium components.

The insoluble sulphates were converted into chlorides and thrice treated with potassium hydroxide and chlorine to precipitate thorium and cerium. From the filtrates the soluble earths were recovered and subjected to a repetition of this treatment. Their oxides after purification were light dirty brown when heated over the Bunsen flame, but grayish white when blasted. Their Mol. W. was 335.5 (At. W. 143.7); their nitrate solution was pink and gave the characteristic didymium component absorption bands altogether free from those of the erbium constituents.

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Cerium and thorium were separated by a combination of the ammonium oxalate and thiosulphate methods. The weighed thoria was pure white, the ceria of a pale salmon color.

The condition of the uranium was shown by its precipitability as tetrafluoride on dissolving the mineral in hydrofluoric acid. This reaction afforded a ready means of estimating with exactness the ferrous iron by permanganate after rapidly filtering off the fluorides precipitated in an atmosphere of carbon dioxide. Solution of the mineral in a sealed tube with dilute sulphuric acid allowed of finding the oxygen value of both $UO_2$ and FeO by permanganate. The result thus found for $UO_2$ agreed marvelously well with that calculated from the $U_3O_8$ found gravimetrically in a separate portion.

| | Hillebrand. | | Mackintosh. | |
|---|---|---|---|---|
| | | Molecular ratios. | | Molecular ratios. |
| $SiO_2$ | 29.63 | 0.4938 | 29.17 | 0.4861 |
| $TiO_2$ | .05 | | | |
| $ThO_2$ | 10.85 | .0470 | 12.00 | .0483 |
| $UO_2$ | [a]1.64 | | [b].79 | |
| $Ce_2O_3$ | 3.07 | | 1.86 | |
| $La_2O_3$, etc | [c]5.18 | | [d]2.94 | |
| $Y_2O_3$, etc | [e]43.45 | | [f]22.67 | |
| " | | .1930 | [g]5.30 | .1864 |
| " | | | [h]4.50 | |
| " | | | [i]14.03 | |
| $Al_2O_3$ | | | .55 | |
| $Fe_2O_3$ | .76 | | | |
| FeO | 1.96 | | | |
| MnO | .88 | | 2.89 | |
| PbO | .80 | .0608 | .77 | .0655 |
| CaO | .67 | | .85 | |
| MgO | .16 | | .60 | |
| $H_2O$ above 105° C | .32 | | .79 | |
| $H_2O$ below 105° C | .04 | | | |
| $CO_2$ | .11 | | | |
| $P_2O_5$ | .12 | | | |
| N, Hc, Fl, Alk | diff .31 | | | |
| | 100.00 | | 99.75 | |

[a] Volumetrically. Gravimetrically 1.62 per cent.
[b] Given as .83$UO_3$ by Mackintosh.
[c] At. W. 143.8 (Mol. W. 335.6).
[d] At. W. 162 (Mol. W. 372).
[e] At. W. 106.8 (Mol. W. 265.6).
[f] At. W. 110.3 (Mol. W. 268.6).
[g] At. W. 110.53 (Mol. W. 269.06).
[h] At. W. 114.9 (Mol. W. 277.8).
[i] At. W. 120 (Mol. W. 288).



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Nitrogen (?) and helium (?) were obtained quantitatively by fusing the mineral with sodium-potassium carbonate in a current of carbon dioxide and collecting the gases in a nitrometer over potassium hydroxide. The volume was between one and two cubic centimeters per gram of yttrialite. The gases were not further examined.

The analysis is given above, together with that of Mackintosh for comparison.

The ratios of Mackintosh's analysis as calculated above by me are certainly wrong in so far as they are affected by the value for iron, which he assumed to be wholly ferrous. If corrected in accordance with the statement of my analysis, or, what amounts to the same thing for the purpose of illustration and is simpler, if my ratio is altered to conform to his statement for RO and $R_2O_3$ bases, it becomes .0644: .1882—a very close agreement.

It is altogether probable that Mackintosh's separations of the earths were not so far reaching as mine, and this belief is borne out by the differences in the experimental molecular weights for the lanthanum and yttrium groups, mine being more in accordance with what might be expected and, moreover, agreeing almost exactly with those which were found by me for rowlandite in 1893, namely, 336.8 and 266.2 respectively.[a]

It is of course impossible to say what disposition should be made of the small amounts of firmly held water, phosphorus, carbon dioxide, fluorine, and alkalies. The ratios of my analysis are, therefore, to a slight extent incorrect, but probably not enough to influence any conclusions that may be drawn. One thing is apparent, that the preliminary purification by acid has had no pronounced effect on the composition of the mass acted on, otherwise Mackintosh's and my analyses should show far greater differences in the main constituents.

The crude empirical formulas deducible from the ratios of the two analyses are nearly

| | | | | |
|---|---|---|---|---|
| Hillebrand | $R''_{61}$ | $R'''_{386}$ | $R''''_{47}$ | $(Si_2O_7)_{247}$ |
| Mackintosh | $R''_{65}$ | $R'''_{373}$ | $R''''_{48}$ | $(Si_2O_7)_{243}$ |

[a] The three minerals gadolinite, yttrialite, and rowlandite occur in Llano County in most intimate association, suggestive of close community of origin, a suggestion which is emphasized by the marvelous agreement for gadolinite and yttrialite, not only in the relative proportions of the trivalent earth metals but in their absolute amounts as well.

| | $Ce_2O_3$ | $La_2O_3$, etc. | $Y_2O_3$, etc. |
|---|---|---|---|
| Gadolinite (Genth) | 2.65 | 5.22 | 44.35 |
| Do | 2.66 | 5.01 | 4.45 |
| Gadolinite (Eakins) | 2.62 | 5.22 | 41.55 |
| Yttrialite (Hillebrand) | 3.07 | 5.18 | 43.45 |
| Rowlandite (Hillebrand) | 5.06 | 9.34 | 47 70 |

This concordant testimony of three analysts may be regarded as strong evidence of the correctness of the earth separations made by them in these cases. Nearly the same relation is shown by the trivalent earth-metals of rowlandite, as seen in the table above.

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there being a slight *deficiency* of oxygen atoms in each case for the radical $Si_2O_7$, which is increased by allowing for the $CO_2$ and $P_2O_5$.

In so far then as the character of the acid radical is concerned the results of Mackintosh's analysis are fully confirmed, and there is absolutely no ground for accepting Benedicks's basic formula, which, as I have already shown (p. 62), is based on a palpable error. But the ratios are not at all such as to lend themselves to ready resolution into isomorphous salts of the acid $H_6Si_2O_7$. By doing quite unwarranted violence to the analytical data the above formulas might be reduced to

$$R''\ \ R'''_6\ \ R''''\ \ (Si_2O_7)_4$$

which can be readily represented structurally as a single complex molecule or as a mixture of molecules like $3R'''_2Si_2O_7+R''R''''Si_2O_7$. In neither case, however, is the type of the rowlandite molecule approached, which requires an altogether different ratio of monoxide, dioxide, and trioxide bases; nor, if the second be accepted, is it at all clear that the two molecules would be mineralogically equivalent—that is, isomorphous.

An alternative hypothesis is to regard the mineral as a mixture containing the anhydrous thorite molecule. Proceeding on this assumption and deducting all thorium and uranium and the proper amounts of silicon and oxygen, the crude empirical formulas become

| | | | |
|---|---|---|---|
| Mackintosh | $R''_{65}$ | $R'''_{373}$ | $Si_{438}O_{1501}$ |
| Hillebrand | $R''_{61}$ | $R'''_{386}$ | $Si_{447}O_{1533}$ |

which may be interpreted as basic salts of metasilicic acid:

| | | | | |
|---|---|---|---|---|
| | $R''_{65}$ | $R'''_{185}$ | $(R'''O)'_{187}$ | $(SiO_3)_{438}$ |
| | $R''_{61}$ | $R'''_{194}$ | $(R'''O)'_{192}$ | $(SiO_3)_{447}$ |
| or | $R''$ | $R'''_3$ | $(R'''O)'_3$ | $(SiO_3)_7$ |

this last being easily susceptible of symmetrical representation in graphic form.

On the whole, I prefer to leave the constitution of yttrialite unsettled until further evidence can be gathered, either from analyses of allied minerals or from yttrialite itself of more certain purity than any that has yet been discovered.

It must not be forgotten that the gases other than $CO_2$ contained in the mineral may be the cause of the inability to arrive at satisfactory conclusions in the case of this and all other minerals which contain them, as I have already pointed out on page 63.

My excuse for such a lengthy publication on a matter still unsettled is the desire to prevent general acquiescence in the grouping under one type of minerals which can by no means be regarded as proved to belong to that type, and to which yttrialite certainly does not belong.

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## SUMMARY.

The empirical formula of Hidden and Mackintosh for yttrialite is confirmed, and it is shown that the basic formula of Benedicks rests on error and has no standing.

The formula of Hidden and Mackintosh is not, however, susceptible of representation as a simple salt of the acid $H_6Si_2O_7$. On the purely hypothetical assumption of admixture of anhydrous thorite, the remaining constituents afford ratios conforming quite closely to those of a basic metasilicate $R''\,R'''_3(R'''O)'_3\,(SiO_3)_7$.

It is shown for two reasons fully discussed that the formula proposed by Benedicks for thalénite is to be regarded as doubtful.

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# A PSEUDO-SERPENTINE FROM STEVENS COUNTY, WASHINGTON.

By F. W. Clarke.

In the course of an investigation upon the ornamental stones of Stevens County, Wash., Mr. R. W. Thatcher and Prof. Elton Fulmer, of the State Agricultural Experiment Station, examined a supposed serpentine which proved to have quite anomalous composition. To the unaided eye the rock was ordinary serpentine of a typical yellowish green color; it was fairly homogeneous, and capable of receiving a fine polish. Incomplete analyses, however, by both of the above-named chemists showed that it was not serpentine, and as I had been consulted with regard to the interpretation of the data, a sample was sent to me for more exhaustive study.

According to Prof. S. Shedd of the Washington Agricultural College, who is conducting the investigation, the rock is from the quarry of the United States Marble Company, 12 miles north and west from Valley, a station on the Spokane Falls and Northern Railroad. It outcrops on the face of a high bluff at an elevation of about 4,070 feet above sea level, and forms a wedge-shaped mass cutting across the mountains in a direction 5° west of north. The adjacent rocks are slates, which lie conformably upon a very coarsely crystalline, dark, almost black, magnesian carbonate. The "serpentine" itself varies a good deal in color, and a series of samples in the United States National Museum show that the output of the locality is far from uniform. They range from a white carbonate, through various intermediate mixtures of the verde antique type, to material which appears to be ordinary serpentine. The latter, however, as shown by the serpentine under consideration, is distinctly laminated in structure, and exhibits a splintery fracture. An analysis by Mr. George Steiger gave the following results:

| | |
|---|---|
| $SiO_2$ | 13.08 |
| $Al_2O_3$ | 1.63 |
| $Fe_2O_3$ | 1.25 |
| FeO | .19 |
| MgO | 56.44 |
| CaO | .33 |
| $H_2O$ at 160° | .85 |
| $H_2O$ above 100° | 23.94 |
| $CO_2$ | 2.03 |
| | 99.74 |



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These figures at once suggest a probable admixture of brucite with the serpentinous material, and a microscopic examination by Mr. J. S. Diller tends to confirm this supposition.

According to Mr. Diller the specimen is mainly composed of three minerals, *a*, *b*, and *c*. The first two have nearly equal indices of refraction, but differ widely in birefringence. The mineral *a* is the most abundant. In transmitted light it is colorless, but between crossed nicols it exhibits brilliant colors. The mineral *b* is pale green, and intermingled with *a*. Its birefringence yields weak colors, quite characteristic of chlorite. In quantity it is less than one-fourth of *a*.

Mineral *c* is granular, in scattered grains and irregular groups with a high index of refraction and a birefringence which suggests a carbonate, but it does not effervesce with a dilute acid. It amounts to not more than 5 per cent of the whole. Mineral *b* is certainly chlorite, and *a* may be brucite or possibly serpentine.

By applying Mr. Diller's observations to the analysis of the rock, the proximate composition of the latter may be deduced; although certain assumptions must be made. The carbonate present is probably hydromagnesite, for that species is a frequent associate of brucite. The composition of the chlorite is unknown, but it may be interpreted as essentially clinochlore, and as proportional to the ferric oxide and alumina. So much assumed, the analysis gives the following approximate results expressing the composition of the specimen:

| | |
|---|---|
| Hydromagnesite | 5 |
| Chlorite | 14 |
| Serpentine | 20 |
| Brucite | 60 |
| Extraneous water | 1 |
| Total | 100 |

In this, four minerals appear instead of three, but the microscopic examination did not attempt to discriminate between the brucite and the serpentine.

In order to obtain evidence confirmatory of the foregoing conclusions, a few experiments were made, tending toward fractional determinations. Upon digesting the powdered rock for two hours with cold, dilute nitric acid (10 per cent by volume), 1.32 per cent of $Fe_2O_3+Al_2O_3$ and 47.29 per cent MgO went into solution. In a similar experiment with cold, 20 per cent acetic acid, 0.69 $Fe_2O_3+Al_2O_3$ and 45.64 MgO were extracted. Brucite dissolves readily in acids of the indicated strength, but some chlorite was evidently attacked as well. I also found that ordinary serpentine was quite appreciably acted upon by weak acetic acid. These experiments, then, merely show that the rock contains a large amount of magnesium in a very easily soluble

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condition, the quantity equivalent to 60 per cent of brucite being 41.4. The results are in harmony with the conclusions already reached, and help to support them, although accurate fractional determinations can not be made. The rock is unusual in character, and if the sample examined is fairly characteristic of the entire deposit, the latter should be carefully studied in reference to its origin and its geological relations.

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# ON "CALIFORNITE."

By F. W. CLARKE and GEORGE STEIGER.

In 1901 Mr. G. F. Kunz[a] called attention to a remarkable massive variety of vesuvianite, discovered in California by Mr. A. E. Heighway, and which at first was thought to be jade. A second locality for the mineral, remote from the first, was found some time later, and here the vesuvianite was accompanied by another substance, which proved upon examination to be an unusual modification of garnet. For the vesuvianite Mr. Kunz proposed the varietal name "californite," and at first the garnet was supposed to be the same species, but different in color. Samples of all three minerals were sent to the laboratory of the United States Geological Survey for analysis, and the results obtained are given below.[b]

A. Vesuvianite from the south fork of Indian Creek, 12 miles from Happy Camp, Siskiyou County, Cal.

B. Vesuvianite from Fresno County, Cal., 35 miles east of Selma.

C. White garnet, found with or near vesuvianite B.

| | A. Vesuvianite. | B. Vesuvianite. | C. Garnet. |
|---|---|---|---|
| $SiO_2$ | 35.86 | 36.55 | 38.59 |
| $Al_2O_3$ | 18.35 | 18.89 | 22.24 |
| $Fe_2O_3$ | 1.67 | .74 | .45 |
| FeO | .39 | .74 | .36 |
| MnO | .05 | none | .10 |
| MgO | 5.43 | 2.33 | .64 |
| CaO | 33.51 | 35.97 | 35.97 |
| $H_2O$ at 105° | .29 | .58 | .31 |
| $H_2O$ above 105° | 4.18 | 3.42 | .80 |
| $TiO_2$ | .10 | none | none |
| $CO_2$ | ..... | .91 | .39 |
| $P_2O_5$ | .02 | ..... | ..... |
| F | none | .13 | .17 |
| | 99.85 | 100.26 | 100.02 |
| Less O=F | ..... | .05 | .07 |
| | ..... | 100.21 | 99.95 |
| Specific gravity | ..... | 3.359 | 3.586 |

[a] Mineral Resources U. S. for 1901, U. S. Geol. Survey; 1902, p. 747. Also, more fully, Am. Jour. Sci., 4th ser., vol. 16, 1903, p. 397.

[b] Analyses by George Steiger.



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These analyses may be reduced to uniform type as follows: Throw out hygroscopic water, $P_2O_5$, and $CO_2$, with the equivalent amount of lime representing calcite. Recalculate $TiO_2$ to equivalent $SiO_2$; $Fe_2O_3$ to $Al_2O_3$; FeO, MnO, and MgO to CaO, and F to $H_2O$. Then recompute to 100 per cent. The reduced analyses are as follows:

| | Analyses. | | | Molecular ratios. | | |
|---|---|---|---|---|---|---|
| | A. | B. | C. | A. | B. | C. |
| $SiO_2$ | 35.58 | 37.28 | 39.09 | 0.589 | 0.617 | 0.647 |
| $Al_2O_3$ | 19.24 | 19.74 | 22.82 | .188 | .193 | .223 |
| CaO | 41.03 | 39.42 | 37.22 | .731 | .703 | .664 |
| $H_2O$ | 4.15 | 3.56 | .87 | .231 | .197 | .048 |
| | 100.00 | 100.00 | 100.00 | | | |

Analysis C gives the garnet ratios quite sharply, but as the mineral was white and massive, somewhat resembling chalcedony, its nature was at first unsuspected. Its density is that of garnet, however, its fusibility is the same, and in thin section under the microscope it is optically isotropic. It is undoubtedly garnet containing as an impurity about 1 per cent of calcium carbonate.

Analyses A and B are less easily interpreted. B gives approximately the empirical formula: $2H_2O$, $2Al_2O_3$, $7CaO$, $6SiO_2$; or, constitutionally,

$$Al_2Ca_7(SiO_4)_6(AlOH)(AlO_2H_2)H.$$

If part of the water is extraneous, the following much simpler formula may hold:

$$Al_2Ca_7(SiO_4)_6(AlOH)_2;$$

and this fairly represents a good many other analyses of vesuvianite, but not all. Vesuvianite varies in composition, and its variations are rather troublesome to interpret, for they may signify either actual differences in the mineral itself, alterations, or impurities. The formula proposed by one of us[a] some years ago,

$$Al_2Ca_6(SiO_4)_5(AlOH),$$

is a good expression for the average composition of the species, but it does not fit the extremes.

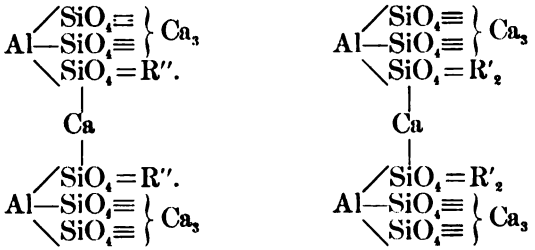
[a] Clarke, Bull. U. S. Geol. Survey No. 125, p. 25.

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A careful study of over 40 analyses of vesuvianite leads us to suspect that it may be a mixture of several similar molecules, which we can represent by the subjoined expressions:

$$Al_2Ca_7(SiO_4)_6(AlOH)_2,$$
$$Al_2Ca_7(SiO_4)_6(AlO_2H_2)_4,$$
$$Al_2Ca_7(SiO_4)_6H_4,$$
$$Al_2Ca_7(SiO_4)_6Ca_2;$$

the first and third compounds usually predominating. Structurally, and with due regard to the analogy between vesuvianite and other species, these formulæ may be written as follows:




About one-seventh of the calcium is replaced by magnesium, and in the variety wiluite the group BOH, analogous to AlOH, probably occurs.

Vesuvianite, then, is to be regarded as a basic orthosilicate, belonging to a group of compounds of which garnet is the normal salt. Epidote and the scapolites are other members of the same class, and their formulæ are all strikingly similar to one another. As products of contact metamorphism they originate under like conditions, and they all undergo alteration in much the same way, yielding similar or even identical derivatives. Garnet, vesuvianite, epidote, and the scapolites must be considered together if the problem of their constitution is to be properly solved.

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# THE ACTION OF SILVER NITRATE AND THALLOUS NITRATE UPON CERTAIN NATURAL SILICATES.

By GEORGE STEIGER.

The following investigation is practically a continuation of the experiments which were described by Clarke and Steiger in a recent bulletin of the United States Geological Survey,[a] although the new work is along somewhat different lines.

In the former research the alkalies and alkaline earth metals of certain silicates were replaced by ammonium, when the minerals were heated in sealed tubes with ammonium chloride. In the present work, silver nitrate and thallous nitrate have been substituted for ammonium chloride, the temperature employed being somewhat above their fusing points. As was anticipated, the alkalies and alkaline earth metals were replaced by the heavy metal, thus giving additional data relative to the constitution of the minerals.

The experiments were carried out as follows: The very finely ground material was mixed thoroughly with various amounts of nitrate by grinding in an agate mortar, the mixture was placed in a tube of Jena glass, and the tube was sealed. These tubes were then heated in a bomb furnace for the specified time and temperature, then opened and the contents leached with boiling water till the filtrate gave no test for nitrates. The residue was then dried and analyzed.

In a recent paper,[b] the writer gave the results of some preliminary work on analcite and chabazite.

Heumann[c] prepared a silver ultramarine by boiling the native mineral with a solution of silver nitrate, and A. H. Church[d] made a silver phillipsite by allowing a solution of silver nitrate to act on the natural mineral at ordinary temperatures for almost three years.

For the optical notes in the present paper, the writer is indebted to Messrs. W. T. Schaller and J. S. Diller.

The crystals in all cases were too small to permit a determination of their forms. A few optical observations were made, and with the exception of the isotropic compounds, it can be said that all were entirely crystalline.

[a] Bull., U. S. Geol. Survey No. 207.
[b] Am. Jour. Sci., ser. 4, vol. 14, July, 1902, p. 31.
[c] Lieb. Ann., vol. 199 (1879), p. 253.
[d] Min. Mag., 1899, vol. 12, p. 9.



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## ANALCITE.

The analcite upon which the following experiments were made was well crystallized material from Table Mountain, near Golden, Colo.

Three silver derivatives were prepared as follows:

A. Ammonium analcite was heated in a sealed tube with four times its weight of dry silver nitrate for 4 hours at 250°–290° C., then leached with boiling water and the residue dried on the water bath.

B. The natural analcite was heated in a sealed tube with four times its weight of dry silver nitrate for 4 hours at 250°–290° C., then leached and the residue dried on the water bath.

C. Same as B, but heated 6 instead of 4 hours.

D. Analysis of the analcite upon which the experiments were made.

Analysis gave the results shown below:

| | A. | B. | C. | D. |
|---|---|---|---|---|
| $SiO_2$ | 42.69 | 41.31 | 40.08 | 55.72 |
| $Al_2O_3$ | 18.22 | 16.44 | 16.29 | 23.06 |
| $Ag_2O$ | 32.01 | 37.45 | 36.91 | ..... |
| CaO | ..... | ..... | ..... | .17 |
| $Na_2O$ | .68 | .85 | .81 | 12.46 |
| $H_2O-$ | ..... | ..... | ..... | .13 |
| $H_2O+$ | 6.09 | 4.29 | 5.86 | 8.26 |
| $NH_3$ | .69 | ..... | ..... | ..... |
| | 100.38 | 100.34 | 99.95 | 99.80 |
| In leach water: | | | | |
| $Na_2O$ | .60 | 13.13 | 12.57 | ..... |

The products were all perfectly white, showing that no free silver oxide contaminated the residue. Under the microscope a small amount of the material showed double refraction, but the larger portion of it was isotropic like the original mineral.

Residue A was boiled for 15 minutes with a 5 per cent solution of sodium carbonate, and only a trace of silica passed into solution. With nitric acid the silver analcite gives sandy silica, and does not gelatinize on evaporation.

A portion of residue B was heated on the water bath for 2½ hours with a 10 per cent solution of sodium hyposulphite and afterwards washed with water. In the residue 9.45 per cent of $Na_2O$ was found, showing that the silver salt had been converted back into the sodium compound, though not completely, the theoretical amount of $Na_2O$ required being 14.1 per cent. Whether a hydrated salt had been formed was not determined. After treatment in a similar manner with potassium cyanide 10.04 per cent of $K_2O$ was found in the residue.

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Considering the various amounts of alkali contained in the silver residues as unaltered analcite, deducting the equivalent amount and reducing the remainder to 100, the above analyses give the results shown below:[a]

| | A. | B. | C. | Theoretical $AgAlSi_2O_6.H_2O$. |
|---|---|---|---|---|
| $SiO_2$ | 40.39 | 40.28 | 39.21 | 39.35 |
| $Al_2O_3$ | 17.27 | 15.92 | 15.90 | 16.72 |
| $Ag_2O$ | 36.65 | 39.78 | 39.16 | 38.03 |
| $H_2O$ | 5.69 | 4.02 | 5.73 | 5.90 |
| | 100.00 | 100.00 | 100.00 | 100.00 |

For comparison, there is given in the last column the percentage composition of theoretical silver analcite. Residue B shows a deficiency of water, possibly owing to the use of too high a temperature in drying the powder before analysis. Residue C gives the following molecular ratios:

$$26Ag_2O,\ 24Al_2O_3,\ 100SiO_2,\ 49H_2O,$$

agreeing well with the empirical formula

$$AgAlSi_2O_6.H_2O.$$

Two thallium derivatives were prepared from the same lot of analcite, as follows:

E. Natural analcite was heated in a sealed tube with four times its weight of thallous nitrate, twenty-four hours at 250°–290° C.

F. Same as E, except that the heating was continued for forty-eight hours. The composition of the two leached residues is given below.

| | E. | F. |
|---|---|---|
| $SiO_2$ | 34.40 | 32.66 |
| $Al_2O_3$ | 15.73 | 13.62 |
| $Tl_2O$ | 47.29 | 53.01 |
| $Na_2O$ | .60 | .12 |
| $H_2O-$ | .62 | .20 |
| $H_2O+$ | .76 | .40 |
| | 99.40 | 100.01 |

[a] In these and all other deductions made in this work the theoretical molecule has been assumed, in this case, $NaAlSi_2O_6H_2O$.

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Both of the preparations were perfectly white. The microscopic examination showed thallium analcite to be mainly isotropic, with a few crystals having double refraction, as was the case with the silver derivative. The thallium compound is easily decomposed by nitric acid, giving sandy silica.

Deducting from analysis F analcite equivalent to 0.12 per cent of $Na_2O$, and reducing to 100, the analysis becomes:

| | Residue F. | Theoretical $TlAlSi_2O_6$. |
|---|---|---|
| $SiO_2$ | 32.61 | 31.33 |
| $Al_2O_3$ | 13.60 | 13.32 |
| $Tl_2O$ | 53.79 | 55.35 |
| | 100.00 | 100.00 |

In the second column is given the calculated percentage composition of normal thallium analcite.

The molecular ratios of F are

$$24Tl_2O,\ 23Al_2O_3,\ 100SiO_2.$$

A closer agreement with theory could hardly be expected.

In the case of the silver compound, the one molecule of water of the original mineral has been retained, and it is essentially analcite with silver replacing sodium. It is not so with the thallium derivative, nor with the ammonium compound of the former investigation. In both of these derivatives the water of the original mineral was lost, the formula being that of leucite with thallium or ammonium replacing potassium, leucite being a mineral closely related to analcite.

One crude experiment was made to show the action of lead nitrate on this mineral. Natural analcite was heated in a sealed tube with a 10 per cent solution of lead nitrate for six hours at about 200° C. The composition of the washed and dried residue follows:

| | | Molecular ratios. |
|---|---|---|
| $SiO_2$ | 60.24 | 100.0 |
| $Al_2O_3$ | 17.55 | 17.1 |
| PbO | 14.75 | 6.1 |
| $Na_2O$ | 6.03 | 9.7 |
| $H_2O$ | undet. | ..... |
| | 98.67 | ..... |

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Water was not determined, but, as will be seen from the summation, it is an unimportant constituent of the compound. Evidently the anhydrous salt has been formed, but incompletely, for only about half the sodium had been replaced.

The molecular ratios are as follows:

$$6PbO, 10Na_2O, 17Al_2O_3, 100SiO_2,$$

or, combining the monoxide bases,

$$16RO, 17Al_2O_3, 100SiO_2.$$

In this a large excess of silica appears.

## LEUCITE.

The specimen of leucite at hand was impure, and more careful work was therefore deferred until some future time, when it may be possible to prepare an artificial mineral which will be studied in detail.

One preparation of the impure leucite was made by heating the native mineral in a sealed tube with four times its weight of thallous nitrate for twenty-four hours at a temperature of 250°–290° C. The leached residue was dried on the water bath. The analysis of this residue follows.

| | Residue. | Molecular ratios. |
|---|---|---|
| $SiO_2$ | 36.00 | 100.0 |
| $Al_2O_3$ | 16.32 | 26.7 |
| $Tl_2O$ | 42.77 | 16.8 |
| $K_2O$ | 4.26 | 7.5 |
| $H_2O-$ | .10 | ..... |
| $H_2O+$ | .20 | 1.8 |
| | 99.65 | |

Combining potassium with thallium, the analysis gives the following:

$$24(TlK)_2O, 27Al_2O_3, 100SiO_2, 2H_2O.$$

This indicates that the same molecule has been formed as in the case of analcite.

## THOMSONITE.

The thomsonite used was well crystallized material from Table Mountain, Colorado. Only one derivative of this mineral was made. The thomsonite was heated in a sealed tube with four times its weight of dry silver nitrate, 20 hours, at 250°–290° C. The residue was dried at about 40° C. Its composition is given on the page following.

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| | Natural thomsonite. | Silver thomsonite. |
|---|---|---|
| $SiO_2$ | 41.13 | 33.80 |
| $Al_2O_3$ | 29.58 | 23.21 |
| $Ag_2O$ combined | ..... | 23.50 |
| $Ag_2O$ free | ..... | 2.56 |
| CaO | 11.25 | 7.28 |
| $Na_2O$ | 5.31 | .71 |
| $H_2O-$ | 1.01 | .45 |
| $H_2O+$ | 12.12 | 8.11 |
| | 100.40 | 99.62 |
| In leach water: | | |
| CaO | ..... | 2.68 |
| $Na_2O$ | ..... | 5.04 |

The color of this residue was dark, showing that some silver oxide had been formed, so contaminating the salt. A determination of this free silver oxide was made by the following method, and it appears in the analysis as "$Ag_2O$ free."

A portion of the silver thomsonite was weighed out in a platinum boat and placed in a glass tube, which was connected with a weighed calcium chloride tube; low red heat was then applied and at the same time a current of dry air was passed over it. At this temperature silver oxide is decomposed, liberating the entire amount of oxygen. The loss of weight in the boat was water plus oxygen, the gain in the tube was water alone; the difference represented the oxygen of the free silver oxide.

The new compound dissolves easily in dilute nitric acid to a clear solution, which forms a perfect jelly on evaporation. Under the microscope the material proved to be entirely crystalline, showing parallel extinction.

Deducting free silver oxide, and also the water lost below 100°, and reducing to 100 per cent, the analysis gives the results tabulated below:

| | Silver thomsonite reduced. | Molecular ratios. |
|---|---|---|
| $SiO_2$ | 34.99 | 100.0 |
| $Al_2O_3$ | 24.02 | 40.3 |
| $Ag_2O$ | 24.32 | 18.0 |
| CaO | 7.54 | 23.2 |
| $Na_2O$ | 0.74 | 2.1 |
| $H_2O$ | 8.39 | 80.0 |
| | 100.00 | |

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The reaction here is incomplete, but the thomsonite ratios have been fairly well preserved.

As the water of this mineral is usually considered to form no part of the chemical molecule, in the following formula it has been represented separately.

For this and the two minerals to follow, the formulæ proposed by F. W. Clarke have been adopted, regarding them as mixtures of salts of orthosilicic and trisilicic acids. The analysis gives the subjoined ratios:

$$18Ag_2O,\ 23CaO,\ 2Na_2O,\ 40Al_2O_3,\ 100SiO_2,\ 80H_2O.$$

Combining monoxide bases, we have

$$R''_{43}Al_{80}Si_{100}O_{363}.80H_2O;$$

which gives a ratio of orthosilicic to trisilicic acids of

$$73SiO_4:\ 9Si_3O_8.$$

Substituting these, we have

$$R''_{43}Al_{80}(SiO_4)_{73}(Si_3O_8)_9.\ 80H_2O;$$

and combining the two acid radicles under the indiscriminate symbol X we have

$$R''_{43}Al_{80}X_{82}.80\ H_2O=1\text{-}2\text{-}2,\ 2H_2O.$$

The analysis of thomsonite reduced in the same way gives the formula

$$R''_{42}Al_{85}(SiO_4)_{76}(Si_3O_8)_8.\ 98H_2O,$$

or, condensed,

$$R''_{42}Al_{85}X_{84}.98H_2O=1\text{-}2\text{-}2,\ 2\tfrac{1}{2}H_2O.$$

## CHABAZITE.

The chabazite used in the following work was the well crystallized flesh-colored material from Wassons Bluff, Nova Scotia.

Two silver derivatives were made, as follows:

A. Ammonium chabazite was heated in an open tube with four times its weight of dry silver nitrate for six hours at 300° C.

B. Natural chabazite was heated in a sealed tube with four times its weight of dry silver nitrate for twenty-four hours at 250°–290° C.



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C. Analysis of the original chabazite:

| | A. | B. | C. |
|---|---|---|---|
| $SiO_2$ | 38.84 | 34.95 | 50.78 |
| $Al_2O_3$ | 11.02 | 11.89 | 17.18 |
| $Fe_2O_3$ | ..... | ..... | .40 |
| $Ag_2O$ | 28.95 | 39.63 | ..... |
| CaO | ..... | ..... | 7.84 |
| $Na_2O$ | ..... | .40 | 1.28 |
| $K_2O$ | ..... | ..... | .73 |
| $H_2O-$ | ..... | 2.38 | 5.22 |
| $H_2O+$ | ..... | 4.40 | 16.63 |
| $N_2O_5$ | ..... | 6.64 | ..... |
| | ..... | 100.29 | 100.06 |
| In the leach water: | | | |
| $Al_2O_3$ | ..... | none | ..... |
| CaO | ..... | 7.75 | ..... |
| $Na_2O$ | ..... | 1.98 | ..... |

This preparation was light in color, showing that no appreciable amount of free silver oxide could have been present. It was decomposed easily by nitric acid, giving sandy silica.

The microscopic examination showed the material to be entirely crystalline and uniaxial.

In this, and as will be shown later in the thallium derivatives also, important amounts of $N_2O_5$ have been retained. This is not due to incomplete washing, but the nitrate is firmly held within the molecule. This same mineral gave, with ammonium chloride, a compound containing-chlorine. What the presence of these small amounts of the acid radicles may mean is not known, but in the following reductions $N_2O_5$ will be considered as combined directly with silver or thallium; the proper amount will be subtracted from the analysis.

Deducting water below 100° and also silver nitrate, analysis B becomes:

| | Residue B. | Molecular ratios. |
|---|---|---|
| $SiO_2$ | 45.30 | 100.0 |
| $Al_2O_3$ | 15.41 | 20.0 |
| $Ag_2O$ | 33.07 | 19.0 |
| $Na_2O$ | .52 | 1.1 |
| $H_2O$ | 5.70 | 42.0 |
| | 100.00 | ..... |

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This gives the following molecular ratios:

$$19Ag_2O,\ 1Na_2O,\ 20Al_2O_3,\ 100SiO_2,\ 42H_2O.$$

Combining sodium with silver, we have

$$R''_{20}Al_{40}Si_{100}O_{280}.42H_2O.$$

Hence the ratio between orthosilicic and trisilicic acids becomes

$$10SiO_4.30Si_3O_8;$$

and combining them under the symbol X, the formula is

$$R''_{20}Al_{40}X_{40}.42H_2O = 1\text{–}2\text{–}2,\ 2H_2O.$$

Reducing the same way the analysis for chabazite, we have

$$R''_{20}Al_{40}X_{40}.109H_2O = 1\text{–}2\text{–}2,\ 5\tfrac{1}{2}H_2O.$$

The two formulæ are

Native chabazite ..... $R''_{20}Al_{40}(SiO_4)_{10}(Si_3O_8)_{30}.109H_2O.$
Silver chabazite ..... $R''_{20}Al_{40}(SiO_4)_{10}(Si_3O_8)_{30}.42H_2O.$

Here calcium has been replaced by silver with a loss of three and one-half molecules of water.

The thallium derivatives were prepared with the same lot of chabazite. Two preparations were made, as follows:

D. Chabazite was heated in a sealed tube with four times its weight of thallous nitrate, forty-eight hours at 250°–290° C.

E. Treated the same as D, but heated for sixty-seven hours.

| | D. | | | E. | |
|---|---|---|---|---|---|
| | Residue found. | Residue reduced. | Molecular ratios. | Residue found. | Residue reduced. |
| $SiO_2$ | 28.92 | 36.31 | 100.0 | 29.44 | 34.44 |
| $Al_2O_3$ | 10.75 | 13.50 | 21.8 | 11.11 | 13.00 |
| $Tl_2O$ | 51.58 | 47.39 | 18.4 | 52.11 | 49.61 |
| $CaO$ | .65 | .81 | 2.3 | .64 | .75 |
| $Na_2O$ | .28 | .35 | 1.0 | .35 | .41 |
| $H_2O$ | 1.30 | 1.64 | 14.7 | 1.53 | 1.79 |
| $H_2O-$ | 2.85 | ..... | ..... | 2.60 | ..... |
| $N_2O_5$ | 3.54 | ..... | ..... | 2.50 | ..... |
| | 99.87 | 100.00 | ..... | 100.28 | 100.00 |
| In the leach water: | | | | | |
| $Al_2O_3$ | ..... | ..... | ..... | None. | ..... |
| $CaO$ | ..... | ..... | ..... | 7.09 | ..... |
| $Na_2O$ | 1.54 | ..... | ..... | 1.58 | ..... |

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Both of these residues were perfectly white and entirely crystalline.

Thallium chabazite is easily decomposed with nitric acid, yielding sandy silica.

Derivative D gives the following ratios:

$$18Tl_2O,\ 2CaO,\ 1Na_2O,\ 22Al_2O_3,\ 100SiO_2,\ 15H_2O;$$

or, combining monoxide bases,

$$R''_{21}Al_{44}Si_{100}O_{287}.15H_2O.$$

The ratio of the two acid radicles is

$$16SiO_4 : 28Si_3O_8;$$

and, inserting these in the formula, we have

$$R''_{21}Al_{44}(SiO_4)_{16}(Si_3O_8)_{28}.15H_2O;$$

or, condensed,

$$R''_{21}Al_{44}X_{44}.15H_2O = 1-2-2+aq.$$

A rough experiment was made by heating silver chabazite in a sealed tube with a 10 per cent solution of lead nitrate. The residue after washing and drying contained 5.59 per cent $Ag_2O$ and 20.24 per cent PbO.

## STILBITE.

The specimen of stilbite used came from Wassons Bluff, Nova Scotia. The action of silver nitrate upon this mineral was not investigated.

One thallium derivative was made by heating the stilbite in a sealed tube with four times its weight of thallous nitrate sixty-five hours at 230°–280° C. The residue was perfectly white, entirely crystalline, and biaxial, and it gave sandy silica with nitric acid. The analysis follows:

| | Stilbite. | Residue. | Molecular ratios. |
|---|---|---|---|
| $SiO_2$ | 55.41 | 36.75 | 100.0 |
| $Al_2O_3$ | 16.85 | 11.74 | 18.8 |
| $Fe_2O_3$ | .18 | ..... | ..... |
| $Tl_2O$ | ..... | 42.94 | 16.5 |
| CaO | 7.78 | .68 | 2.0 |
| $Na_2O$ | 1.23 | .15 | .3 |
| $H_2O-$ | 3.60 | 5.48 | ..... |
| $H_2O+$ | 15.41 | 2.29 | 20.8 |
| | 100.46 | 100.03 | ..... |

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Omitting water lost below 100°, we have the following ratios:

$$16\ Tl_2O,\ 2\ CaO,\ 1\ Na_2O,\ 19\ Al_2O_3,\ 100\ SiO_2,\ 20\ H_2O;$$

and, combining monoxide bases,

$$R''_{19}Al_{38}Si_{100}O_{276},\ 20\ H_2O;$$

which gives a ratio between the two acid radicles of

$$7\ SiO_4 : 31\ Si_3O_8.$$

Inserting these in the formula, it becomes

$$R''_{19}Al_{38}(SiO_4)_7(Si_3O_8)_{31}.20\ H_2O,$$

which condenses to

$$R''_{19}Al_{38}X_{38}.20\ H_2O.$$

Reducing the analysis of stilbite in the same way, we get

$$R''_{17}Al_{36}(SiO_4)_4(Si_3O_8)_{32}.93\ H_2O = 1-2-2,5\ H_2O.$$

From the last three minerals we get the following formulæ:

| | |
|---|---|
| Native thomsonite | $R''_{42}Al_{85}(SiO_4)_{76}(Si_3O_8)_8.98H_2O = 1-2-2,2\frac{1}{2}H_2O.$ |
| Silver thomsonite | $R''_{43}Al_{80}(SiO_4)_{73}(Si_3O_8)_9.80H_2O = 1-2-2,2H_2O.$ |
| Native chabazite | $R''_{20}Al_{40}(SiO_4)_{10}(Si_3O_8)_{30}.109H_2O = 1-2-2,5\frac{1}{2}H_2O.$ |
| Silver chabazite | $R''_{20}Al_{40}(SiO_4)_{10}(Si_3O_8)_{30}.42H_2O = 1-2-2,2H_2O.$ |
| Thallium chabazite | $R''_{21}Al_{44}(SiO_4)_{16}(Si_3O_8)_{28}.15H_2O = 1-2\ \ 2,Aq.$ |
| Native stilbite | $R''_{17}Al_{36}(SiO_4)_4(Si_3O_8)_{32}.93H_2O = 1-2-2,5H_2O.$ |
| Thallium stilbite | $R''_{19}Al_{38}(SiO_4)_7(Si_3O_8)_{31}.20H_2O = 1-2-2,Aq.$ |

The similarity of the foregoing formulæ is plainly evident. Leaving water out of consideration, and except in the single case of silver thomsonite, the ratios agree closely with the ratios of 1–2–2 for the monoxide base, aluminum, and silicic acid. It will be seen that with the two silver derivatives, compounds retaining two molecules of water were formed, although in the case of thomsonite a mineral hydrated with $2\frac{1}{2}$ molecules of water was taken, while the chabazite contained $5\frac{1}{2}$.

## NATROLITE.

The natrolite which was studied came from Bergen Hill, N. J. Two silver derivatives were made, as follows:

A. Natrolite was heated in a sealed tube with a 10 per cent solution of silver nitrate, eighteen hours at 120° C.

B. Natrolite was heated in a sealed tube with four times its weight of dry silver nitrate, twenty-two hours at 250°–290° C.

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| | A. | B. | B. reduced. | Molecular ratios. |
|---|---|---|---|---|
| $SiO_2$ | 40.45 | 34.70 | 36.25 | 100.0 |
| $Al_2O_3$ | 10.24 | 18.54 | 19.36 | 31.4 |
| $Ag_2O$ combined | 20.48 | 32.30 | 33.73 | 24.0 |
| $Ag_2O$ free | | 3.91 | | |
| CaO | .93 | 2.50 | 2.61 | 7.6 |
| $Na_2O$ | 7.84 | .39 | .41 | 1.0 |
| $H_2O$ | | 7.32 | 7.64 | 70.2 |
| | | 99.66 | 100.00 | |

Both preparations were very dark, showing that a quantity of free silver oxide had been deposited. The compound formed is easily decomposed by warm dilute nitric acid, giving a perfectly clear solution which gelatinizes upon evaporation. Under the microscope, it showed perfect crystallization.

Neglecting free silver oxide, residue B gives the following formula:

$$24Ag_2O, 8CaO, 1Na_2O, 31Al_2O_3, 100SiO_2, 70H_2O,$$

or, combining monoxide bases,

$$R'_{66}Al_{62}Si_{100}O_{326}, 70H_2O,$$

which corresponds roughly to the formula $R_2Al_2Si_3O_{10}.2H_2O$. The ratios are not so good as could be desired, but are close enough to show that this compound has probably been formed.

One thallium derivative was made by heating natrolite in a sealed tube with six times its weight of thallous nitrate for forty-eight hours, at 250°–290° C. The analysis gave the following results:

| | Residue. | Molecular ratios. |
|---|---|---|
| $SiO_2$ | 26.10 | 100.0 |
| $Al_2O_3$ | 15.59 | 35.1 |
| $Tl_2O$ | 55.64 | 30.1 |
| CaO | .67 | 2.8 |
| $Na_2O$ | .34 | 1.1 |
| $H_2O-$ | .51 | |
| $H_2O+$ | .66 | 8.5 |
| | 99.51 | |

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This compound is perfectly white. It is easily dissolved by dilute nitric acid, giving a perfect jelly on evaporation.

The optical observations were: Double refraction low, cleavage vertical, extinction parallel, probably biaxial. It was entirely crystalline. The molecular proportions are as follows:

$$30Tl_2O,\ 3CaO,\ 1Na_2O,\ 35Al_2O_3,\ 100SiO_2,\ 9H_2O;$$

or, combining monoxide bases,

$$R'_{68}Al_{70}Si_{100}O_{339}.\ 9H_2O,$$

which corresponds closely to the formula $R_2Al_2Si_3O_{10}$.

## SCOLECITE.

The scolecite used came from Whale Cove, on the island of Grand Manan, New Brunswick.

One derivative was made by heating the scolecite in a sealed tube with four times its weight of silver nitrate six hours at 250°–280° C. The residue was dried at about 35° C.

| | Scolecite. | Residue. | Molecular ratios. |
|---|---|---|---|
| $SiO_2$ | 45.86 | 37.28 | 100.0 |
| $Al_2O_3$ | 25.78 | 21.54 | 34.0 |
| $Ag_2O$ combined | ..... | 20.21 | 14.0 |
| $Ag_2O$ free | ..... | 6.67 | ..... |
| CaO | 13.92 | 5.40 | 15.5 |
| $Na_2O$ | .41 | .44 | 1.1 |
| $H_2O-$ | .40 | .46 | ..... |
| $H_2O+$ | 13.65 | 7.92 | 70.8 |
| | 100.02 | 99.92 | ..... |

This residue was dark brown, owing to the silver oxide it contained. On heating over the low flame of the Bunsen burner in order to reduce the silver oxide to metallic silver it turned perfectly white.

On attempting to mount this preparation for microscopic examination the balsam became very dark, which prevented any optical observations from being made.

The molecular ratios for this derivative are:

$$14Ag_2O,\ 16CaO,\ 1Na_2O,\ 34Al_2O_3,\ 100SiO_2,\ 71H_2O,$$

or, uniting monoxide bases,

$$R'_{62}Al_{68}Si_{100}O_{333},\ 71H_2O.$$

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These proportions agree fairly well with the formula

$$R'_2Al_2Si_3O_{10}, +aq.$$

The reaction in this case was incomplete, only a little over one-half the calcium and none of the sodium being replaced, but the experiment shows that the desired molecule was partially formed.

## MESOLITE.

The mesolite studied was a fine specimen of crystalline material from Österö, in the Faroe Islands.

One thallium derivative was prepared by heating the mesolite in a sealed tube with four times its weight of dry thallous nitrate for eighty hours at 240°–280° C.

Its analysis and that of the mesolite follow:

| | Mesolite. | Residue. | Molecular ratios. |
|---|---|---|---|
| $SiO_2$ | 45.97 | 29.11 | 100.0 |
| $Al_2O_3$ | 25.98 | 16.94 | 34.2 |
| $Tl_2O$ | ..... | 44.75 | 21.7 |
| CaO | 9.69 | 2.90 | 10.8 |
| $Na_2O$ | 4.79 | .26 | .8 |
| $H_2O-$ | 1.34 | 3.32 | ..... |
| $H_2O+$ | 12.04 | 3.06 | 35.0 |
| | 99.81 | 100.34 | ..... |
| In the leach water: | | | |
| $Al_2O_3$ | ..... | None. | ..... |
| CaO | ..... | 5.50 | ..... |
| $Na_2O$ | ..... | 4.42 | ..... |

The leached residue was perfectly white and entirely crystalline, with parallel extinction. It gave a perfectly clear solution with acid, which gelatinized on slight evaporation.

The molecular ratios are as follows:

$$22Tl_2O,11CaO,1Na_2O,34Al_2O_3,100SiO_2,35H_2O.$$

Combining monoxide bases, we have

$$R'_{68}Al_{68}Si_{100}O_{336}.35H_2O,$$

agreeing almost perfectly with the formula

$$R'_2Al_2Si_3O_{10}.H_2O.$$

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These three minerals and their derivatives give the following comparison, when all the monad and dyad bases are united under R″:

Native natrolite.....$R''_{36}Al_{66}Si_{100}O_{335}\cdot 72\ H_2O$
Silver natrolite.....$R''_{33}Al_{62}Si_{100}O_{326}\cdot 70\ H_2O$
Thallium natrolite.....$R''_{34}Al_{70}Si_{100}O_{339}\cdot 9\ H_2O$
Native scolecite.....$R''_{34}Al_{66}Si_{100}O_{333}\cdot 99\ H_2O$
Silver scolecite.....$R''_{31}Al_{68}Si_{100}O_{333}\cdot 71\ H_2O$
Native mesolite.....$R''_{33}Al_{66}Si_{100}O_{332}\cdot 87\ H_2O$
Thallium mesolite.....$R''_{34}Al_{68}Si_{100}O_{336}\cdot 35\ H_2O$

Since, as others have shown, the water in these three minerals plays no part in the chemical molecule, it has been placed as a separate constituent in the formulæ.

The ratios found are not so sharp as could be desired, nor have the reactions been complete, but they indicate that the three minerals are all derived from the trisilicic acid $H_8Si_3O_{10}$.

Deducting from each of the above formulæ the water contained in the undecomposed mineral, which latter is represented by the amount of alkali retained by the derivative, we have the water contents:

Silver natrolite.....70 $H_2O$ less 18 $H_2O$ equals 52 $H_2O$
Thallium natrolite.....9 $H_2O$ less 8 $H_2O$ equals 1 $H_2O$
Silver scolecite.....71 $H_2O$ less 50 $H_2O$ equals 21 $H_2O$
Thallium mesolite.....35 $H_2O$ less 29 $H_2O$ equals 6 $H_2O$

We have here, as was the case with the thomsonite, chabazite, and stilbite derivatives, silver compounds strongly hydrated, while the thallium salts are practically anhydrous.

## PECTOLITE.

The pectolite came from Bergen Hill, N. J. It contained a small amount of calcium carbonate as an impurity.

A single silver derivative was made by heating the pectolite in a sealed tube with four times its weight of dry silver nitrate, for twenty-two hours at 240°–280° C. The residue was dried on the water bath. On analysis the following results, stated below, were obtained.

| | Pectolite. | Residue. | Molecular ratios. |
|---|---|---|---|
| $SiO_2$ | 53.34 | 39.05 | 100.0 |
| $Al_2O_3$ | .33 | .38 | ..... |
| $Ag_2O$ | ..... | 32.57 | 21.5 |
| CaO | 33.23 | 18.13 | 49.8 |
| MnO | .45 | ..... | ..... |
| $Na_2O$ | 9.11 | 5.99 | 14.9 |
| $H_2O-$ | .27 | ..... | ..... |
| $H_2O+$ | 2.70 | 4.12 | 35.2 |
| $CO_2$ | .67 | ..... | ..... |
| | 100.10 | 100.24 | ..... |

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The derivative was dark, but on heating over the bunsen burner the color disappeared, and on treating the ignited residue with nitric acid red fumes were given off, showing that a quantity of free silver oxide was present. This was not determined, but is contained in the figures given for $Ag_2O$. The silver oxide reported is therefore several per cent too high.

The compound is easily decomposed by warm dilute nitric acid, with the separation of sandy silica. A complex breaking up of the molecule has taken place and no simple ratios appear.

## ELÆOLITE.

Elæolite from Litchfield, Me., was heated in the usual way with thallous nitrate. An incomplete analysis of the leached residue gave the following results:

| | |
|---|---|
| Insoluble in nitric acid | 46.34 |
| $Al_2O_3$ | 27.90 |
| $Tl_2O$ | 8.50 |
| $Na_2O+K_2O$ | 15.40 |
| Water, etc | undet. |

In the leach water was found 2.13 per cent of sodium and potassium oxides. The analysis shows that elæolite is but slightly attacked by treatment with thallous nitrate.

## ÆGIRITE.

Ægirite from Magnet Cove, Arkansas, was heated in a sealed tube with dry silver nitrate. The following results were obtained on analysis of the leached residue:

| | |
|---|---|
| Insoluble in nitric acid | 91.22 |
| $Al_2O_3+Fe_2O_3$ | 1.18 |
| CaO | small |
| $Ag_2O$ | 4.12 |
| $Na_2O$ | .53 |
| Water, etc | undet. |

This mineral has evidently been but little altered by the action of silver nitrate.

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# DUMORTIERITE.

By WALDEMAR T. SCHALLER.

## INTRODUCTION.

Dumortierite was discovered by Gonnard[a] in November, 1879, at Chaponost, near Lyons, France, and was made the subject of a brief note by E. Bertrand in 1880. The following year, Gonnard named the mineral after Eugene Dumortier, the eminent French paleontologist.

The mineral was known to be new from its optical properties before its chemical composition was determined, its beautiful pleochroism being especially marked. Damour soon after made an analysis of the mineral, from which he obtained the formula $4\ Al_2O_3, 3\ SiO_2$.

Specimens of this mineral from New York, previously taken for indicolite, were studied by Diller and Riggs and shown to be different from tourmaline. At about the same time dumortierite from Arizona became known, and analyses of the mineral from both localities were made. These analyses all showed the presence of boric acid in varying amounts, and also a small quantity of water. An occurrence of dumortierite in Norway was afterward noted, and still later several localities in Germany were mentioned.

In 1902, Ford published three analyses of dumortierite, one on material from New York, a second on material from Arizona, and a third on material from a new locality in San Diego County, Cal. In the same paper he mentions a second new locality, the fourth one in this country, in Skamania County, Wash. He showed by his analyses that dumortierite contains boric acid and water in nearly constant amount.

A careful search for crystals was made in a large quantity of the California mineral, which resulted in the finding of two small, imperfect but measurable examples. On looking over the Arizona material in the National Museum a third crystal was found. Three crystals were also obtained among specimens from New York. These were carefully measured and some crystallographic data were thus obtained.

The mineral is usually sparingly present in small fibrous masses scattered through the rock, making it difficult to obtain any consider-

[a] For references see Literature, pp. 119–120, this bulletin.



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able quantity of it in a pure condition. At the California locality the mineral occurs in large, pure masses, very favorable for chemical investigation. From an analysis made by the writer on the California material, a formula was deduced in which the boric acid and water have a certain fixed value. The other analyses are discussed, and it is shown that they all agree fairly well with the new formula proposed by the writer. An analysis of the Washington dumortierite is also given. Ford tested the French material qualitatively for boric acid and obtained a strong positive reaction.

While a more or less complete study of the mineral has been made, it is fully realized that in no sense can the work be called complete. The material for crystallographic study was poor, and it is very much hoped that better crystals will at some future time be found. The determinations of optical constants are very meager, for the usual condition of occurrence of the mineral is not favorable to such study. Only a few analyses are available for any discussion of the composition of the mineral, and though dumortierite does not contain a large number of constituents, many more analyses—but only extremely accurate and reliable ones—will be gladly welcomed.

It was found that the California material differed somewhat in its properties from normal dumortierite. The color is lavender instead of blue, the pleochroism is colorless to red purple instead of blue, and the mineral contains 1½ per cent titanium oxide. It is of especial interest to correlate these differences, as it adds another good example to that class of silicates which contain a small amount of titanium and (seemingly thereby) acquire a purple pleochroism.

## OCCURRENCES.

### FOREIGN.

#### FRANCE.

Dumortierite[a] is found at several places in the vicinity of Lyons (Rhone), where it occurs in a pegmatite gneiss. At Beaunan, on the road from Oullins to Chaponost, it is found in a small quarry in gneiss in slender blue fibers in the midst of veinlets or lenses of feldspar and pegmatite. At Brignais it occurs in very small fibers disseminated throughout a white pegmatite, associated with large black tourmalines, garnets, muscovite, and cordierite, the latter being largely altered to mica. In some cases bluish tourmaline and dumortierite have the vertical axis in common. Pseudomorphs of mica after dumortierite are frequent.

The mineral has a good cleavage parallel to $a$ {100} and an imperfect prismatic one. There are also "planes of separation" parallel to the base. Twins, analogous to those of aragonite, are frequent. The

[a] Lacroix, A., Minéralogie de la France, vol. 1, 1893–1895, pp. 15–19.

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color is blue, sometimes nearly black. Inclusions are not prominent, though bubbles and rutile have been noticed.

The axial plane is parallel to $b\{010\}$. $Bx_a$ (negative) perpendicular to $c\{001\}$. In the twins the axial planes of the two parts make an angle of about 60°. $\beta$ is about 1.65, and the birefringence is about .010. The axial angle ($2V_{Na}$) is near 35° to 40°. The dispersion is energetic $\rho<v$. Pleochroism is very strong; $\mathfrak{b}=\mathfrak{c}$, colorless or very pale blue; $\mathfrak{a}$, cobalt blue or violet. Some of the specimens from Brignais are of a rose-salmon color, a little redder than andalusite. The maximum absorption is (contrary to that of tourmaline) in the direction of elongation (parallel to $c$). The presence of idiophanous figures is also noted. According to Damour, the blue color of the mineral may perhaps be due to traces of $Ti_2O_3$, the presence of which in the French mineral has, however, not been demonstrated. It is noticed that the small fibers of dumortierite are often inclosed in a white mica, which is gradually replacing the original mineral.

### GERMANY AND AUSTRIA.

The mineral is found near Schmiedeberg, Silesia,[a] in the pegmatite of the lower Val Donbastone, in long fibers of a green or greenish-blue color. These fibers have a thickness of 1 mm. and reach a maximum length of 50 mm. They are often bent, and inclose pieces of quartz. On one fiber a prism angle of 69° 6′ was measured. Prismatic cleavage, imperfect, was noted. The pleochroism is very strong: $\mathfrak{c}=\mathfrak{b}$, colorless; $\mathfrak{a}$, pistachio-green. Cross sections show the emergence of an acute bisectrix (negative), the axial angle being somewhat smaller than that of muscovite. With a crystal refractometer the following values for the indices of refraction were obtained:

$$\alpha=1.678$$
$$\beta=1.686$$
$$\gamma=1.689$$
$$\gamma-\alpha=\ .011$$

An analysis of impure material was also made.

In a clayey residue, the mineral has been found at Imligan, near Chodan, and Schobrowitz, near Carlsbad, in Bohemia, and in clayey sandstone at Oberbris, near Pilsen, in Bohemia. These residues are probably formed from decomposing pegmatite, from which the dumortierite originally came. The mineral shows a strong pleochroism; $\mathfrak{a}$, deep carmine to smalt blue and, in places where partly decomposed, dark olive to red brown; $\mathfrak{b}$, light gray olive to colorless. The (negative) acute bisectrix is parallel to the elongation. The obtuse bisectrix is perpendicular to the cleavage plates ($a=\{100\}$). The

[a] See Literature, pp. 119–120.

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associated minerals are tourmaline, quartz, feldspar, muscovite, biotite, chrysoberyl, apatite, garnet, and chlorite.

NORWAY.

The mineral is found at Tvedestrand in minute fibers in cordierite gneiss. The pleochroism is as follows:

$\mathfrak{c} = \mathfrak{b}$, pale yellow, almost colorless.
$\mathfrak{a}$, intense cobalt blue.

Cross sections show a prismatic angle of about 60°. The birefringence (.010) is feeble. Pleochroic halos (in yellow) are very characteristic. The axial angle (2V) is about 35°, and the dispersion strong $\rho > v$. The associated minerals are cordierite and sillimanite.

Romberg has described a mineral from Argentina (2.51 per cent $B_2O_3$) which seems to resemble the California dumortierite. The color is lilac and the pleochroism similar to that from California.

## UNITED STATES.

### NEW YORK.

The mineral occurs in that part of New York City known as Harlem. It has been sparingly found as acicular crystals "aggregated in fasces or tufts resembling clippings of hair" in a lode of red granite extending southeastward from Fourth avenue and One hundred and twenty-third street to Madison avenue at One hundred and sixteenth street. At One hundred and seventy-first street and Fort Washington avenue it was found in several pockets in a vein of coarse pegmatite in mica-schist. The vein is about 3 feet wide and the pockets extended for about 80 feet. The body of the vein is granular gray quartz, orthoclase, and flaky muscovite. The dumortierite occurs chiefly in the orthoclase, though it has also been found as long, filiform inclusions in the muscovite, singly and radiating from centers. It has also been noticed at Kips Bay, near the upper end of Riverside Park, in white oligoclase, and at Tenth avenue and One hundred and thirtieth street.

The associated minerals are orthoclase, quartz, muscovite, xenotime, monazite, tourmaline, zircon, torbernite (?), antunite (?), apatite, garnet, and andalusite.

A brief study of several slides of the New York City dumortierite showed that the mineral occurs almost entirely in the orthoclase. Very rarely is it in the quartz or muscovite. It is usually in fibrous forms, with ragged outlines, and in one particular section an orthoclase crystal was filled with minute threads of dumortierite, arranged more or less parallel. In these slides andalusite also was noticed.

Mr. Frederick Braun, of Brooklyn, N. Y., very kindly lent the writer his private collection of New York dumortierite, which probably contains the finest dumortierite specimens ever found in that

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locality. About 25 specimens are shown, the best one containing a prismatic group of fine blue dumortierite fibers 5 cm. long and from one-half to 1 cm. thick. The rock is a pegmatitic gneiss, and consists chiefly of quartz and feldspar, with smaller quantities of biotite, muscovite, black tourmaline, dumortierite, and garnets. The dumortierite occurs in long prisms, often bent, and again broken, the space between being filled with the gneiss rock. The basal cross fracture is common and the color is often changed to a dull gray. At times the fibers are seemingly intergrown with the tourmaline in parallel position. The three crystals described later were obtained from these specimens.

As additional localities, Mr. Braun gives: One hundred and first street and Lexington avenue, New York; One hundred and eighteenth, One hundred and twentieth, One hundred and twenty-second streets and Madison avenue; One hundred and thirty-eighth, One hundred and thirty-ninth, One hundred and fortieth, One hundred and forty-ninth streets and Mott avenue; One hundred and thirty-third, One hundred and thirty-fifth, One hundred and forty-ninth streets and Hudson River Railroad; One hundred and forty-ninth street and Sheerier place; One hundred and seventy-first street and Boulevard.

The mineral possesses a strong pleochroism, ranging from colorless to deep blue, this color being always in the direction of elongation. The extinction is parallel and the mineral orthorhombic. Cleavage parallel to the macropinacoid is perfect, these cleavage plates showing the emergence of an obtuse bisectrix. An imperfect cleavage parallel to the base is also noticed, and basal sections show an imperfect prismatic cleavage. Such sections show the emergence of an acute bisectrix. The mineral is negative. The axial plane is parallel to the brachypinacoid and the orientation is $a=\mathfrak{c}$, $b=\mathfrak{b}$, $c=\mathfrak{a}$. The pleochroism is $\mathfrak{c}=\mathfrak{b}$, colorless; $\mathfrak{a}$, deep blue. Absorption, $\mathfrak{a}>\mathfrak{b}=\mathfrak{c}$. Some sections show polysynthetic twinning lamellæ, but their relation could not be made out.

## ARIZONA.

At Clip, Ariz., dumortierite occurs in a quartz rock which has not been found in place (Doctor Hillebrand), but only as loose bowlders. Dumortierite and quartz form the principal mineral constituents, kyanite, magnetite, and muscovite being present in subordinate amounts. The rock is fine grained and has a blue color due to the dumortierite.

Under the microscope, a section of the rock showed numerous small lath-shaped prisms of dumortierite placed in every direction in a mass of allotriomorphic quartz, with several large blades of muscovite and abundant magnetite, and a little apatite and rutile. Feldspar seems to be entirely absent.

The dumortierite has the usual colorless to blue pleochroism and presents normal properties. In the slide studied it is very fresh and shows no signs of alteration, the muscovite present being primary.

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The quartz grains are (relatively) fairly large and are not crushed like those of the California rock. The rock seems to have undergone no dynamic change after its formation.

The pale-green kyanite has been analyzed by Dr. W. F. Hillebrand with the results given below:

| | |
|---|---|
| $SiO_2$ | 36.30 |
| $Al_2O_3(+TiO_2)$ | 62.51 |
| $Fe_2O_3$ | .70 |
| FeO | undet. |
| CuO | tr. |
| Ign. | .40 |
| | 99.91 |
| Specific gravity | 3.656 at 18.5 |

CALIFORNIA.

This occurrence was first mentioned by Ford, and an analysis of the dumortierite was given by him. The writer made a brief visit to the locality in the summer of 1903 and collected a large quantity of material, which permitted a rather complete study of the mineral. The writer's thanks are due to Mr. John A. Thoman, of San Diego, the owner of the property, for permission to visit the interesting locality and for the privilege of collecting specimens.

The mineral occurs in a dike a few miles east of Dehesa, San Diego County, and is not far from the orbicular gabbro described by Professor Lawson.[a] The general country rock of the region is granite, in which occur large masses of gabbro, of which the orbicular rock is a peculiar phase. Both the gabbro and the granite contain many dikes, and it is in one of these dikes, in decomposed biotite-granite, that the dumortierite occurs. This dike has a length of about 1,000 feet and a thickness of about 30 or 40 feet, strikes S. 70° E., and has a dip of about 70° N. 20° E.

The rock consists chiefly of quartz and either sillimanite or dumortierite. Feldspar is entirely absent from the dike. The dike may be divided into an upper and lower part, according to the character of the rock. The upper part is fine grained and consists of quartz and sillimanite; the lower part is coarse grained and consists of quartz and dumortierite.

The upper part, forming about one-half the dike, is a fine-grained white saccharoidal rock, sometimes of a grayish color, and never contains any dumortierite. It possesses a more or less schistose structure and cleaves off into blocks parallel to the dip. A little muscovite is sometimes present, small crystals of titanium oxide are abundant, and occasionally a little pyrite is seen.

[a] Bull. Dept. Geol. Univ. Cal., vol. 3, 1904, pp. 383–396.

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Microscopically the rock is composed of allotriomorphic quartz, sillimanite prisms arranged in parallel bands (schistose structure), a little muscovite, probably secondary, and accessory titanite, titanium oxide, rutile (?), pyrite, apatite, zircon, and corundum.

The sillimanite occurs both as short and long prisms. The former are usually grouped together in parallel bands which may run across the entire slide or may pinch out at both ends, forming a very flat lens. The prisms are short and stout, usually more or less ragged in outline, with many transverse fractures. The several parts of a single prism thus broken are at times considerably displaced. Again, an entire row of prisms may be broken and displaced. The displacement is always in the direction of elongation of the prism. The ends are usually more or less rounded, and macropinacoidal cleavage is sometimes well developed. Some nearly square cross sections show diagonal cleavage. Titanium oxide and zircon are at times inclosed in the prisms. These prisms occasionally show slight alterations and at times seem to have been entirely removed, forming either an opaque mass or leaving just the outlines of former prisms behind.

The long, slender prisms are placed at all angles and are not grouped in bands as the others are. The edges are sharp and the ends are often terminated by two faces, forming a spear. These prisms are usually smaller than the others and decrease in thickness until they are so narrow as to become entirely opaque. These straight hair-like inclusions were at first taken for rutile or magnetite, but it is thought they are merely sillimanite prisms of extreme thinness.

Optically the two forms are identical, and are to be classified as sillimanite. The relief is distinct and birefringence is rather strong. The direction of elongation is always an axis of minimum elasticity. The crystals are nonpleochroic and always extinguish parallel. Pleochroic halos were not observed.

The quartz is allotriomorphic and is usually much cracked. In general the principal cracks are parallel to the bands of sillimanite, while cracks perpendicular to these bands are also numerous. Many transverse irregular cracks also occur. Some of the quartz grains seem to have been slightly displaced, and the cracks thus formed been filled with secondary quartz. Sometimes the bands of sillimanite have caused "augen" to form. In places the quartz shows large liquid inclusions, and strings of small inclusions, though not common, sometimes occur. Besides the inclusions mentioned and the accessory minerals, the quartz contains in places a large amount of very fine opaque dust, possibly magnetite. Such sections of the quartz as remain dark under crossed nicols show a uniaxial cross with a positive sign in convergent light.

Of the accessory materials, titanium oxide, probably rutile, occurs in the greatest abundance. A few grains are probably titanite, but



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the majority of the small sharply defined crystals are probably rutile. They are at times slightly dichroic (yellow to brown), and occur in equidiametral crystals. Some of the crystals in the bands of sillimanite have been crushed and lengthened out. In one case a crystal of corundum was inclosed in rutile. Zircon is also widely distributed in irregular grains, usually of minute size. Occasionally a large piece has roughly the usual crystal outline, but seems to have been more or less corroded. One large crystal inclosed several small rutiles. The order of crystallization of the minerals seems to have been as follows: Corundum, rutile (and titanite), zircon, sillimanite, and quartz. It may be that there are two generations of sillimanite. Those long, slender sharp crystals in the quartz may have formed after the crystals in the bands.

An analysis of the rock was made by the writer, giving the results tabulated below:

| | |
|---|---|
| $SiO_2$ | 75.54 |
| $Al_2O_3$ | 18.65 |
| $Fe_2O_3$ | .35 |
| FeO | .06 |
| MgO | none |
| CaO | .03 |
| Alk | none |
| $H_2O-$ | 1.10 |
| $H_2O+$ | 3.67 |
| $TiO_2$ | .48 |
| $ZrO_2$ | .06 |
| $P_2O_5$ | trace |
| $FeS_2$ | .10 |
| | 100.04 |

The large amount of water present is difficult to explain. The inclusions in the quartz account for some, and assuming the presence of some water due to incipient alteration in the sillimanite, there is still a large amount unaccounted for.

From the analysis, neglecting the water and accessory minerals, the composition of the rock is calculated as consisting of

| | |
|---|---|
| Quartz | 69 |
| Sillimanite | 31 |

Deducting the water and other accessory minerals of the rock we obtain the following comparison:

| | Analysis recalculated. | Calculated for above composition. |
|---|---|---|
| $SiO_2$ | 80.3 | 80.5 |
| $Al_2O_3$ | 19.7 | 19.5 |

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As we approach the middle of the dike the rock loses its schistose structure, becomes coarser, and we find occasional masses of dumortierite, which are more and more abundant, until finally we come to what is called the lower part of the dike, consisting of abundant dumortierite and quartz. Very rarely a small black tourmaline or garnet is seen. Muscovite is more or less abundant throughout the entire lower part, and in places forms an essential part of the rock.

The lower part of the dike differs in many ways from the upper. No schistose structure is apparent; the rock is very coarse and has a mottled appearance, due to the dark bunches of dumortierite on the white quartz background.

Some masses of dumortierite are very large, examples 5 by 3 by 3 cm. being not uncommon. They usually have a radiated columnar structure and break off nearly parallel to the base in fairly plane surfaces, which on large pieces become somewhat bowl shaped. As the various fibers are not strictly parallel but radiating, the breakage can only be approximately at right angles to the general elongation of the fibers. These masses of dumortierite weather from the rock and stand out very prominently. They usually have numerous cleavage cracks parallel to the base. The color of the mineral is lavender, resembling to some extent compact rubellite. Connected with this unusual color is the unusual pleochroism that the mineral possesses, being from colorless to red purple instead of blue.

The quartz is coarse grained and has a slight greasy appearance. It sometimes occurs in large masses free from dumortierite. Magnetite is present in small grains as well as titanium oxide—rutile (?). An analysis of a sample of pure quartz was made to prove the absence of any feldspar or other silicate. The analysis follows:

| | |
|---|---|
| $SiO_2$ | 98.78 |
| $Fe_2O_3$ (total) | .45 |
| CaO | .10 |
| MgO | none |
| $TiO_2$ | .61 |
| $P_2O_5$ | trace |
| | 99.94 |

A rarer phase of the rock consists of quartz, muscovite, and dumortierite, which is here present in small pieces but a few millimeters or less thick. The mica is here an essential constituent of the rock and in places becomes abundant.

Microscopically the minerals present in the lower part of the dike are seen to be dumortierite and quartz, with muscovite and sillimanite in small quantities, together with accessory magnetite, titanite, rutile (?), apatite, and zircon, as well as a number of small undetermined inclusions. The dumortierite occurs in irregular masses with ragged outline, often resembling in shape the hornblende of a diorite.

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Again, it forms fan-shaped radiating masses, sometimes of large size. Irregular broken fibrous masses also occur scattered through the slide. The quartz is allotriomorphic and is but slightly cracked. It is rather full of inclusions in places. With the exception of a little muscovite there are no secondary minerals present.

The common form for the dumortierite is shown in radiated fanlike masses that vary considerably in size. When the entire piece is larger than a quadrant, parts of the black cross (seen in spherulites) are seen when the nicols are crossed. These fan-shaped pieces are probably the results of an incomplete spherulitic growth. The most perfect one consists of but half a circle. On certain parts no radiated fibers are detectable, the (prismatic) cleavage lines being perfectly parallel. Some of the pieces become decidedly fibrous toward the ends, and the various individual fibers depart somewhat from true parallelism. In between these fibers fine-grained aggregates of muscovite can often be seen.

A number of pieces showed a (secondary?) growth of fibers, which are probably in all cases dumortierite, as with high powers a faint pleochroism can be detected. They were at first thought to be sillimanite, but they agree in all their properties—so far as can be determined—with dumortierite. These fibers can be classed in two parts.

Those in the first part seem to have been formed as a secondary growth on the main masses of dumortierite. The fibers branch out considerably and often form a radiating fringe around an entire section of the mineral. They penetrate the quartz grains, and interstitial muscovite is absent. The line where they join the main mass of the mineral is usually fairly well defined. In general, the fibers are normal to the edge of the main mass, but locally they vary considerably, especially where they form fanlike groups.

The fibers of the second class clearly represent a stage in the alteration of the dumortierite to muscovite. The solid mass of dumortierite becomes fibrous and, at the edges, breaks up into small fibers, which gradually become loose from the parent mass. The space where they formerly joined is now occupied by a granular mass of muscovite, which also fills the spaces between the fibers. Gradually this process goes on until, finally, we have a large mass of granular muscovite in which are embedded a few fibrous prisms of the original mineral. Fig. 6 shows diagrammatically a stage in the process.

Basal sections present an entirely different appearance. The macropinacoidal cleavage, so well developed on the New York mineral, does not show on the sections of the California mineral. The imperfect prismatic cleavage is present and divides the section up into a multitude of irregular bodies. Occasionally there is a short crack parallel to the brachypinacoid, and it may be that the mineral possesses an imperfect interrupted brachypinacoidal cleavage.

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The prismatic cleavage was found to be parallel to the prism {210}. A large number of measurements gave as the angle {010} ∧ cleavage cracks 62°–67°, averaging 64°–65°. The angle {010} ∧ {210} is 66° 01′. The cleavage cracks are irregular, and it was difficult to obtain any accurate measurements, but the ones made are sufficient to determine the cleavage. They were measured against the trace of the optic axial plane.

Polysynthetic twinning lamellæ were observed a number of times, and in one particular section (the same on which the prismatic cleavage was measured) were determinable to a certain extent. The alternate lamellæ extinguished together, the difference in angle of extinction of two adjacent lamellæ being about 31°. The line joining these lamellæ is parallel to the cleavage or to the prism {210}. The trace of the axial plane is parallel (or nearly so) in adjacent lamellæ.



FIG. 6.—Dumortierite altering to muscovite.

The pleochroism of the mineral is beautiful, especially if the section be not too thin. $\mathfrak{c} = a$ is colorless, $\mathfrak{b} = b$ is colorless to very faint pink, $\mathfrak{a} = c$ is deep-red purple. None of the sections entirely possess the ordinary blue pleochroism. In some slides, however, there are certain small areas of varied and irregular shape which do show the ordinary pleochroism. These small blue areas in the rich red-purple background make a most beautiful combination. On some sections a large area will have a faint bluish-purple color, as if intermediate between the deep-blue and the red purple.

This California dumortierite contains about 1½ per cent titanium oxide, which is considered as $Ti_2O_3$, replacing part of the alumina. Correlating these facts with the other known instances, it seems as if the presence of the titanium controlled the occurrence of this purple pleochroism. Samples of the Washington and Arizona mineral, free from titanite and rutile, and which possess the ordinary colorless to blue pleochroism, were tested qualitatively for titanium with hydrogen peroxide, with a negative result in each case. One might conclude, therefore, that in those areas of a dumortierite section in which the color is blue there is no titanium; that they are molecular centers, so to speak, which are free from titanium. The absorption of the mineral

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is $\mathfrak{a}>\mathfrak{b}=\mathfrak{c}$. Optically it is negative, the acute bisectrix $\mathfrak{a}$ being normal to the base. The axial plane is parallel to the brachypinacoid. The birefringence is higher than that of quartz, though only by a small amount.

The sections of dumortierite show that inclusions are rare. The masses of mineral are usually pure, muscovite being about the only mineral included, and this is not strictly an inclusion, as it is a secondary product, forming along the fibrous cracks of the mineral. In one basal section a number of rutile (?) crystals were observed, but such inclusions are very rare.

The quartz occurs in large allotriomorphic grains, but little cracked and sometimes almost free from inclusions and again thickly crowded with them. In no way does the quartz show the effect of pressure as the quartz of the upper part of the dike does. Occasionally when the nicols are crossed the color of a quartz grain will be somewhat banded, these bands occurring on several grains, being parallel throughout the entire slide. The inclusions are sillimanite, magnetite, rutile (?), and an undetermined mineral.

The rock composing the dike is doubtless an igneous plutonic rock. There would seem to have been an interruption in the stage of formation of the entire dike. The upper or sillimanite-bearing part was more or less completely formed when a mass was pushed into the place now occupied by the lower part of the dike. This mass exerted a great pressure on the already partly formed upper part, giving it its schistose structure. Boric acid in large amount was in the lower mass. Possibly it was a later intrusion and may have caused the increase in pressure of the lower mass, which gradually cooled and formed a borosilicate (dumortierite) and quartz. The absence of dumortierite in the upper part would seem to indicate that the addition of boric acid to the entire mass was a later incident, and had the original magna cooled without this extra intrusion the rock would have been uniform and would have consisted of an aluminum silicate (sillimanite or andalusite) and quartz. The intrusion of the boric acid could not change the character of the upper part, which had already (at least partially) formed, but it did change the character of the lower part. May it be that the pressure determined the formation of sillimanite instead of andalusite?

### WASHINGTON.

Ford mentions this occurrence of dumortierite and gives as the locality "the headwaters of the North Fork of the Washougal River in Skamania County, Wash." Mr. Brereton, of Woodstock, Oreg., very kindly sent the writer a number of specimens, which form the basis of the following notes.

As Ford states, the dumortierite occurs in a new habit, being present as small spherulites up to 3 mm. in diameter.

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The rock in which they occur is a light-colored, fine-grained rock, containing, besides the blue spherulites, patches of a compact, soft, light-green mineral, shown to be muscovite. While the exposed surface of the rock is dark, the fresh portion light gray, rarely becoming almost white. Sometimes the dumortierite occurs so abundantly as to color the entire rock blue. Pyrite is also present and in places is very abundant.

Under the microscope the rock is seen to be very fine grained and to consist of quartz, muscovite, and andalusite in nearly equal proportions. The porphyritic spherulites of dumortierite form a striking feature in the fine-grained rock. The pale-green patches before mentioned are seen to be muscovite. Pyrite is abundant, and a few grains of magnetite (ilmenite?) surrounded by leucoxene are also present. In places the leucoxene is abundant.

The andalusite occurs as short laths with a square cross section and also as irregular more or less opaque masses without definite shape. They are probably in some stage of alteration, possibly to muscovite. While usually very minute, the laths occasionally become quite large relatively. In general, the andalusite surrounding the larger spherulites is much coarser than the main mass, though there are numerous exceptions. When clear and transparent, the laths exhibit the normal properties of andalusite. The relief is moderate and the birefringence low. Imperfect prismatic cleavage is sometimes seen. The prisms are nonpleochroic and pleochroic halos are absent. Extinction is always parallel. The elongation is always in the direction of maximum elasticity.

Sillimanite seems to be entirely absent. Muscovite occurs in the green masses and also in minute particles distributed throughout the entire rock. Nowhere does it occur in plates, as it normally does in granite, but everywhere it is in minute pieces. A good deal is probably derived from the alterations of the andalusite and dumortierite, and it may be possible that all of it is secondary—that the rock originally consisted essentially of quartz and andalusite. An analysis of the green mineral was made on a small amount of material, containing also some andalusite and quartz. It shows the mineral is muscovite, thus corroborating the microscopic evidence.

| | |
|---|---|
| $SiO_2$ | 50.13 |
| $Al_2O_3$ | 32.37 |
| $Fe_2O_3$ (total) | 1.52 |
| MgO | .09 |
| CaO | .15 |
| $H_2O-$ | 1.74 |
| $H_2O+$ | 5.08 |
| $K_2O$ | 9.60 |
| | 100.68 |
| Specific gravity | 2.80 |

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The quartz occurs in allotriomorphic grains, which are so minute and so mixed with the andalusite and muscovite that recourse was had to chemical analysis to verify their determination as quartz.

The dumortierite occurs in small spherulites scattered throughout the rock and occasionally bunched together to form a large patch of blue. On an average they reach a diameter of from one-half to 1 mm. Their shape, while in general circular, is often elliptical and may become very irregular in places. They consist of fibers radially arranged and show the optical phenomena of "spherulites." The dumortierite has parallel extinction, and its birefringence is somewhat higher than that of the quartz and also slightly more than that of the andalusite, though the difference between that of the latter two minerals is very small.

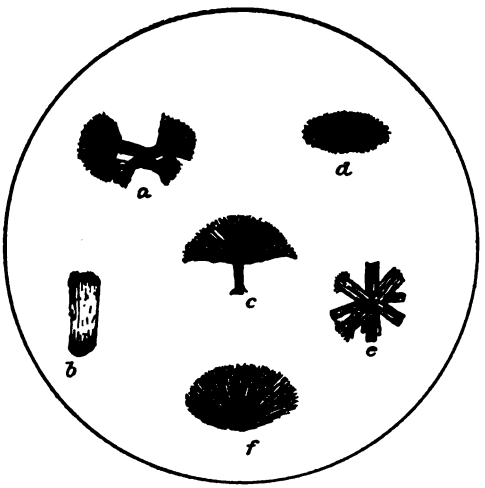



FIG. 7.—Forms of dumortierite.

The intensity of the pleochroism of the dumortierite varies, so that in some spherules there are concentric bands of fibers differing greatly in the depth of their color. Some spherules are almost colorless, and it was at first thought they might be parallel growths of andalusite with the dumortierite, but such a conclusion could not be verified.

The fibers are not always perfectly radial. They are at times gathered into "brushes," and a number of these put together may form a spherulite. The fibers are thus more thickly crowded in some places than elsewhere, and this frequently results in intensifying the pleochroism, so that in some spherulites there are numerous blotches of blue of much deeper color than the rest. Muscovite is frequently plentiful in a spherulite, being formed between the fibers, and is probably an alteration product of the dumortierite. Frequently a mass of dumortierite will be almost completely changed to mica, leaving but small fragments of the original mineral behind.

The fibers of dumortierite, while usually arranged radially, sometimes assume different shapes, and some of the masses of dumortierite seen under the microscope are reproduced in fig. 7.

Fig. 7 shows variations from typical spherulitic form that the fibers of dumortierite assume. *a* is four prisms irregularly joined at the

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center, the ends spreading out into "brushes" of fine fibers. This form is fairly abundant. *b* forms a prismatic portion becoming fibrous at both ends, and while common in the New York, Arizona, and California occurrences, is a rare type for Washington dumortierite. *c* forms a sort of fan and is composed of several "brushes" joined together. It is a common type. *d* is an elliptical spherulite. *e* is a mass of prisms such as *b*, but not spreading out as *a* does. It is of rarer occurrence. *f* is a bunch of radial fibers with no prismatic stem as in *c*. It is fairly common.

To confirm the microscopical determination of the minerals of the rock a chemical analysis was made by the writer of a fresh sample of the rock. The results obtained are shown below.

| | |
|---|---|
| $SiO_2$ | 57.18 |
| $Al_2O_3$ | 34.10 |
| $Fe_2O_3$ | .54 |
| $FeO$ | .28 |
| $MgO$ | .10 |
| $CaO$ | .63 |
| $Na_2O$ | .39 |
| $K_2O$ | 2.57 |
| $H_2O-$ | .69 |
| $H_2O+$ | 2.02 |
| $TiO_2$ | .66 |
| $ZrO_2$ | .02 |
| $CO_2$ | none |
| $P_2O_5$ | .53 |
| $FeS_2$ | .28 |
| $MnO$ | none |
| $BaO$ | .04 |
| $SrO$ | trace? |
| $Li_2O$ | none |
| | 100.03 |

Out of 200 grams of rock, 4.3 grams of dumortierite were obtained. Some was doubtless lost, and the sample still contained some andalusite, but 2 to 2½ per cent would approximately represent the amount of dumortierite present.

The mineralogical composition of the rock is about as follows:

| | |
|---|---|
| Andalusite | 35 |
| Dumortierite | 2 |
| Quartz | 32 |
| Muscovite | 27 |
| Accessories | 4 |
| | 100 |

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The accessories consist of pyrite, magnetite, possibly ilmenite, leucoxene, and apatite. Considering the dumortierite as andalusite and calculating the soda in the analysis as potash, we get the following comparison:

| | Calculated composition. | Found. |
|---|---|---|
| $SiO_2$ | 57.66 | 57.18 |
| $Al_2O_3$ | 33.81 | 34.10 |
| $K_2O$ | 3.19 | 3.16 |
| $H_2O$ | 1.22 | 2.02 |
| Accessories | 4.12 | 3.54 |
| | 100.00 | 100.00 |

It is interesting to compare the minerals from the three western occurrences, where feldspar is entirely absent, and the rock in each case is composed (essentially) of the following materials:

Arizona: Dumortierite, quartz, muscovite, kyanite.

California: Dumortierite, quartz, muscovite, sillimanite.

Washington: Dumortierite, quartz, muscovite, andalusite.

As the three minerals, kyanite, sillimanite, and andalusite have the same chemical composition, the composition of the entire rock is probably also similar.

## CRYSTALLOGRAPHY.

While the writer was at the California locality he made special search for crystals of dumortierite, but is forced to the conclusion that good, perfect crystals of the mineral are yet to be found. A large quantity of seemingly promising material was collected and afterward carefully examined with a lens. One minute crystal was found showing several fairly good faces in the prismatic zone and, when mounted on the goniometer, presenting minute terminal planes giving poor reflections. Further search afforded another crystal showing several prismatic faces but no terminations.

The collection of specimens of dumortierite from Clip, Ariz., in the United States National Museum, was examined, and on one specimen was found a small crystal showing two prism faces and a dome. Further, three small crystals were obtained from the New York mineral. On this poor material the following work is based. The results obtained are perhaps not accurate, but are the best that could be obtained. The California and New York crystals are long prismatic, while the Arizona crystal may be termed short prismatic.

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The mineral is orthorhombic, and from the various measurements the following axial elements have been calculated:

$$\dot{a}=.8897$$
$$\dot{c}=.6871$$

The crystals were measured with the two-circle goniometer, and the values for $p_o$ and $q_o$, from which the above ratios are obtained, are

$$p_o=.7723$$
$$q_o=.6871$$

The forms observed are as follows:

$$b=0\infty=010$$
$$a=\infty 0=100$$
$$l=\infty 2=120$$
$$m=\infty=110$$
$$g=\frac{3}{2}\infty=320$$
$$n=2\infty=210$$
$$d=\frac{1}{2}0=102$$
$$r=\frac{2}{3}0=203$$

Besides these forms, reflections were obtained from several other minute faces, but they were so minute, and the reflections so poor, that their validity is very questionable and they are omitted from the foregoing list. The averages of the measured angles, compared with the calculated values, are shown in the following table:

| Letter and symbol. | Measured. | | | | Calculated. | | | |
|---|---|---|---|---|---|---|---|---|
| | $\phi$. | | $\rho$. | | $\varphi$. | | $\rho$. | |
| | ° | ′ | ° | ′ | ° | ′ | ° | ′ |
| $b=0\infty=010$ | 0 | 00 | 90 | 00 | 0 | 00 | 90 | 00 |
| $a=\infty 0=100$ | 91 | 23 | 90 | 00 | 90 | 00 | 90 | 00 |
| $l=\infty 2=120$ | 29 | 19 | 90 | 00 | 29 | 20 | 90 | 00 |
| $m=\infty=110$ | 49 | 01 | 90 | 00 | 48 | 20 | 90 | 00 |
| $g=\frac{3}{2}\infty=320$ | 59 | 49 | 90 | 00 | 59 | 19 | 90 | 00 |
| $n=2\infty=210$ | 65 | 23 | 90 | 00 | 66 | 01 | 90 | 00 |
| $d=\frac{1}{2}0=102$ | 91 | 21 | 21 | 46 | 90 | 00 | 21 | 07 |
| $r=\frac{2}{3}0=203$ | 87 | 39 | 26 | 58 | 90 | 00 | 27 | 14 |

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The brachypinacoid is present on four crystals, usually as broad faces. Some give relatively good reflections.

The macropinacoid occurs on all crystals, except the one from Arizona, and always as narrow faces. The reflections were poor, but serve to identify the form. The $\phi$ angles measured are as follows:

| | Measured. | Calculated. |
|---|---|---|
| | ° ′ | ° ′ |
| California | 90 02 | |
| Do | 93 46 | |
| Do | 90 00 | 90 00 |
| New York | 92 57 | |
| Do | 91 15 | |
| Do | 90 16 | |

The brachy prism $l=\infty 2=120$ occurs on four crystals as narrow faces giving fair reflections.

| | Measured. | Calculated. |
|---|---|---|
| | ° ′ | ° ′ |
| California | 30 00 | |
| Do | 28 00 | |
| Do | 29 22 | 29 20 |
| New York | 29 34 | |
| Do | 29 39 | |

The unit prism is poorly developed on the California crystals, being present but once as a narrow face giving a poor reflection. On the Arizona crystal it occurs twice as broad faces.

| | Measured. | Calculated. |
|---|---|---|
| | ° ′ | ° ′ |
| California | 48 52 | 48 20 |
| Arizona | 49 16 | |

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The macro prism $g=\frac{3}{2}\infty=320$ is present several times. The measured angles vary somewhat.

| | Measured. | | Calculated. | |
|---|---|---|---|---|
| | ° | ′ | ° | ′ |
| California | 58 | 55 | | |
| Do | 59 | 42 | | |
| Do | 60 | 36 | | |
| Do | 59 | 38 | | |
| Do | 59 | 23 | | |
| Do | 60 | 14 | 59 | 19 |
| New York | 59 | 04 | | |
| Do | 60 | 07 | | |
| Do | 59 | 25 | | |
| Do | 60 | 23 | | |
| Do | 60 | 31 | | |

The macro prism $n=2\infty=210$ is present four times. The reflections were fair.

| | Measured. | | Calculated. | |
|---|---|---|---|---|
| | ° | ′ | ° | ′ |
| California | 65 | 26 | | |
| Do | 65 | 35 | 66 | 01 |
| Do | 65 | 19 | | |
| Do | 65 | 12 | | |

The macro dome $d=\frac{1}{2}0=102$ is present once on the Arizona crystal. The reflections were not very good.

The dome $r=\frac{1}{3}0=203$ is present on one of the California crystals. The face is exceedingly minute and the reflection was poor.

On crystal No. 4 (New York) were observed two very small faces, giving poor reflections.

| | φ. | | ρ. | |
|---|---|---|---|---|
| | ° | ′ | ° | ′ |
| (1) | 83 | 46 | 17 | 54 |
| | 83 | 16 | 17 | 44 |
| (2) | 80 | 19 | 16 | 50 |
| | 84 | 17 | 17 | 28 |

These agree approximately with the symbol {8.1.20}, or considering the form vicinal to a dome, to {205}.

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The combinations seen on the six crystals are as follows:

| | | |
|---|---|---|
| No. 1 | California | *b*, *a*, *l*, —, *m*, *g*, *n*, —, *r*. |
| No. 2 | California | *b*, *a*, *l*, *h*, —, *g*, *n*, —, —. |
| No. 3 | Arizona | —, —, —, —, *m*, —, —, *d*, —. |
| No. 4 | New York | *b*, *a*, —, —, —, *g*, —, —, —. |
| No. 5 | New York | *b*, *a*, *l*, —, —, *g*, —, —, —. |
| No. 6 | New York | —, *a*, *l*, —, —, *g*, —, —, —. |

Fig. 8 shows three of the crystals. A is from California; size, 1 mm. × ¼ mm. B is from New York; size, 1 mm. × ¼ mm. C is from Arizona; size, 1 mm. × 1 mm.

The following table gives the calculation of the forms of dumortierite based on the elements given in this paper. The table corresponds to the forms given in Goldschmidt's Winkeltabellen.

| | | | | | |
|---|---|---|---|---|---|
| a=.8897 | lga=9.94924 | $lga_o$=0.11202 | $lgp_o$=9.88779 | $a_o$=1.2943 | $p_o$=.7723 |
| c=.6871 | lgc=9.83702 | $lgb_o$=0.16298 | $lgq_o$=9.83702 | $b_o$=1.4554 | $q_o$=.6871 |

| No. | Letter. | Sym. Miller. | Sym. gdt. | $\phi$. | $\rho$. | $\xi_o$. | $\eta_o$. | $\xi$. | $\eta$. | $x$ (Prism) $x:y$. | $y$. | d=tg $\rho$. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ° ′ | ° ′ | c ′ | ° ′ | ° ′ | ° ′ | | | |
| 1 | *b* | 010 | 0∞ | 0 00 | 90 00 | 0 00 | 90 00 | 0 00 | 90 00 | 0 | ∞ | ∞ |
| 2 | *a* | 100 | ∞0 | 90 00 | 90 00 | 90 00 | 0 00 | 90 00 | 0 00 | ∞ | 0 | ∞ |
| 3 | *l* | 120 | ∞2 | 29 07 | 90 00 | 90 00 | 90 00 | 29 07 | 60 53 | .5570 | ∞ | ∞ |
| 4 | *m* | 110 | ∞ | 49 01 | 90 00 | 90 00 | 90 00 | 49 01 | 40 59 | 1.1510 | ∞ | ∞ |
| 5 | *g* | 320 | ½∞ | 59 47 | 90 00 | 90 00 | 90 00 | 59 47 | 30 13 | 1.7170 | ∞ | ∞ |
| 6 | *n* | 210 | 2∞ | 65 23 | 90 00 | 90 00 | 90 00 | 65 23 | 24 37 | 2.1825 | ∞ | ∞ |
| 7 | *d* | 102 | ½0 | 90 00 | 21 07 | 21 07 | 0 00 | 21 07 | 0 00 | .3862 | 0 | 0.3862 |
| 8 | *v* | 203 | ⅓0 | 90 00 | 27 14 | 27 14 | 0 00 | 27 14 | 0 00 | .5147 | 0 | .5147 |

The minerals andalusite, sillimanite, staurolite, and dumortierite possess certain properties that are very much alike. They are all orthorhombic, their axial ratios are similar, their principal constituents are silica and alumina, and in many ways these minerals can well be grouped together. Using the word isomorphous in its general loose sense, these minerals are isomorphous. A comparison of their axial ratios is given below:

| | *a*. | *c*. |
|---|---|---|
| Andalusite | .9861 | .7025 |
| Sillimanite | .970 | (?) |
| Staurolite | .9795 | .6942 |
| Dumortierite | .8897 | .6871 |

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For staurolite the values are taken from Goldschmidt's Winkeltabellen with the $a$ and $c$ axes interchanged.

There was some question in the writer's mind as to whether the orientation chosen was the best or whether the present prism {210} had not better be made the unit prism. The cleavage is parallel to this prism, and the twinning also bears some relation to this form. Moreover, the ratio above given for staurolite, though adopted by Goldschmidt, is not, in the writer's opinion, the best one for the mineral. The one given by Dana, who makes the $a$ axis just half as long, would be the better one. The common form of staurolite is prismatic, with a prism angle of 50° 40′ (Dana).

For andalusite, on the other hand, the prismatic angle is 89° 12′ and the $a$ axis should be .9861, as given. Should dumortierite be classed crystallographically with staurolite or with andalusite? Unfortunately, the evidence is almost too meager to decide this question. The unit prism is poorly developed on the California crystals and entirely absent from the New York, the strongest form next to the brachypinacoid being the prism {320}. The prismatic cleavage is parallel to {210}, and making the cleavage form the unit prism the $a$ axis should be given half its present value. On the other hand, the Arizona crystal is of the typical andalusite habit, and, making the prism the unit one, we obtain the axes as here given. Giving staurolite the (approximate) same axes as andalusite and dumortierite, the prismatic cleavage is parallel to the same form as in dumortierite {210}.

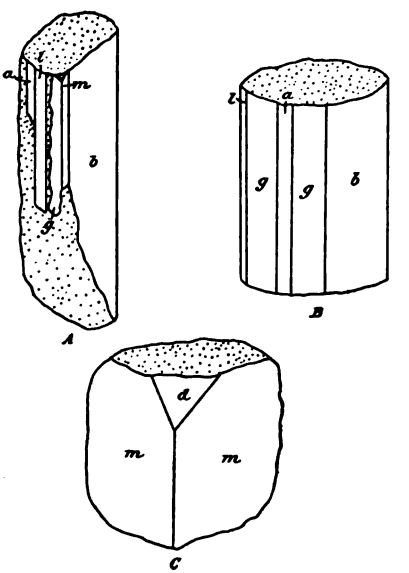


FIG. 8.—Dumortierite.

It may be worth noting that as staurolite and dumortierite are related crystallographically more closely than either with andalusite, the chemical composition of the two former is much more complex than that of the last named species.

## PHYSICAL PROPERTIES.

### GENERAL PROPERTIES.

Macroscopic crystals are exceedingly rare, the mineral usually occurring in prismatic fibrous forms showing no crystal faces. The Washington mineral occurs in spherulitic forms which are but a special arrangement of fibers.

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The cleavage is—macropinacoidal good, prismatic {210} imperfect, and basal imperfect, and perhaps, also, in traces, brachypinacoidal. The New York mineral shows the macropinacoidal cleavage very well, while the California mineral shows the imperfect basal cleavage. The fracture is rough and the fibrous prisms are somewhat brittle, though a mass of fibers is very tough. The hardness is 7.

The following values for the specific gravity have been given:

| | |
|---|---|
| | 3.36 |
| | 3.265 |
| | 3.22 |
| | 3.319 |
| | 3.226–3.43 |
| | 3.211–3.302 |
| Av. | 3.292 |

The writer obtained 3.306 as the density of a piece weighing about 10 grams. A good average value would be 3.30.

The luster is vitreous, somewhat satiny on the fibrous California mineral. The color is usually blue, though also lavender and greenish blue to black. The colors noted are:

France: Blue, black.

Germany: Blue, bluish green.

Sweden: Blue.

New York, Arizona, Washington: Blue.

California: Lavender.

The mineral is usually opaque in its massive form, but the small fibers of the California mineral are transparent to translucent.

## OPTICAL CHARACTERS.

All the determinations made on the mineral from different localities have given the same orientation. The axial plane is parallel to the brachypinacoid, the acute bisectrix is normal to the base. The mineral is negative.

The following are the pleochroisms noted on the mineral from different localities: Colorless to cobalt blue, pale yellow or colorless to cobalt blue, colorless to pistachio green, colorless to rose salmon, colorless to deep carmine, colorless to red purple (California).

### AXIAL ANGLES.

On the Norway mineral, $2V_{Na}$ was determined as about 35°. Linck states that the angle is somewhat less than that of muscovite.

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The axial angle on the California dumortierite is small. The following measurements were made with the microscope and micrometer ocular, and represent only approximate values:

$$2E_{Li} = 33°$$
$$2E_{Na} = 37$$
$$2E_{Cu} = 42$$

The dispersion thus is $\rho < \upsilon$.

### INDICES OF REFRACTION.

Linck obtained for the dumortierite from Germany

$$\alpha = 1.678$$
$$\beta = 1.686$$
$$\gamma = 1.689$$
$$\alpha - \gamma = .011$$

Michel Levy and Lacroix give $(\gamma - \alpha) = .010$ with the dispersion (strong) $\rho > \upsilon$, while Bertrand in his original description gives $\rho < \upsilon$ as the dispersion. The value $(\gamma - \alpha)$ for quartz is .009 and for andalusite .011. The birefringence for dumortierite is always a little higher than that of the quartz, and in the Washington mineral very nearly that of the andalusite.

### PYROGNOSTICS.

The mineral is infusible before the blowpipe, but loses its color, becoming white. It gives a blue color on heating with cobalt nitrate. If the mineral be very finely powdered and intimately mixed with potassium bisulphate and calcium fluoride and the powder be carefully introduced into the flame, a green color, due to the boric acid, may be momentarily seen, but it is an exceedingly difficult reaction to obtain.

## CHEMICAL COMPOSITION.

In 1881, after the first announcement of the discovery of the mineral had been made by Gonnard, Damour gave the following analysis of the mineral:

| | |
|---|---|
| $SiO_2$ | 29.85 |
| $Al_2O_3$ | 66.02 |
| $Fe_2O_3$ | 1.01 |
| MgO | .45 |
| Ign. | 2.25 |
| | 99.58 |
| Specific gravity | 3.36 |

From this analysis the formula $4Al_2O_3,3SiO_2$ was calculated. Damour did not suspect the presence of boric acid in the mineral, and what was weighed as alumina probably contained several per cent



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$B_2O_3$. In 1887 Riggs gave an analysis of the New York mineral, in which he found 4 per cent $B_2O_3$. Two years later Whitfield gave several analyses of American dumortierite, all showing the presence of $B_2O_3$. In 1899 Linck gave some observations on the mineral, including an analysis by W. Schimpff, showing a strong test for boric acid. In 1902 Ford gave us three analyses of American dumortierite and also mentioned two new localities. During the winter of 1903–4 the writer made an analysis of the California dumortierite collected by himself during the previous summer. An analysis was also made at the same time of the Washington dumortierite kindly furnished by Mr. Brereton.

Believing that one good analysis is better than several poorer ones for the exact determination of the formula of the mineral, there will be presented an analysis of the California dumortierite made by the writer. From this a formula has been calculated for the mineral, and it will be shown how the other analyses agree with this proposed formula. Before giving the results a few preliminary words will not be out of place.

An analysis of dumortierite is a difficult operation. The small amount of silica makes it difficult to get a good fusion. On preliminary trials on an analysis of the California dumortierite, it was found that what was weighed as silica in the regular course of the analysis contained more or less of the undecomposed mineral. Results of about 30 to 32 per cent were obtained. This is, of course, on the uncorrected silica. It was found that a second fusion of the supposed silica was not only very beneficial, but also necessary. What was then weighed as silica contained but little residue. The handling of so large an amount of alumina is very cumbersome, and an accurate determination of the alumina (plus iron and other oxides here precipitated) is difficult. The boric acid determination is tedious and difficult. The accurate determination of the water, which is given off only at a high temperature, is also not easy. One can thus see that an analysis of such a mineral is a troublesome operation and that a greater allowance must be made than for most silicate analyses.

The specimen analyzed was selected in the field, an exceedingly pure piece weighing about 10 grams being chosen. The specific gravity of this piece was taken by suspension in water, giving 3.306. This was broken into small pieces and carefully examined for muscovite, quartz, or other minerals. Sections of the mineral showed that the dumortierite was free from any inclusions. No grains of any titanium mineral abundant in the quartz could be detected. When the mineral was powdered it was treated with heavy solution, of specific gravity 3.10, and a minute amount of mineral (muscovite?) stayed on top and was removed. The separation was repeated several times, and the powder was dried at 100° and carefully examined under the

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microscope for impurities. None was found. The mineral was unquestionably pure.

The general analytical methods used were those pursued in the Survey laboratory for silicate analyses, with a few modifications. The mineral was fused with sodium carbonate, the silica separated and re-fused with sodium carbonate. The silica was filtered off, weighed, and treated with HF, which left some residue. The alumina (plus iron and titanium) was precipitated three times to be sure of removing all of the sodium salts. It was ignited and weighed with the silica residue, fused with sodium bisulphate, some silica recovered, the iron was reduced and determined by titration and the titanium was determined colorimetrically. The presence of titanium was suspected from the color of the pleochroism of the mineral. The boric acid was determined by the Gooch method, using all of the known precautions. The mineral was twice fused with sodium carbonate and the boric acid was finally weighed as calcium borate. The water was collected in a calcium chloride tube, the mineral being heated in a Gooch tubulated crucible in the usual manner. A blank determination was run before and after each water determination and a small correction applied. All possible precautions were taken throughout the analysis, which was made in duplicate. The results are given below.

| | 1. | 2. | Average. |
|---|---|---|---|
| $SiO_2$ | 28.58 | 28.78 | 28.68 |
| $Al_2O_3$ | 63.31 | 63.30 | 63.31 |
| $Ti_2O_3$ | 1.49 | 1.40 | 1.45 |
| $Fe_2O_3$ | .21 | .25 | .23 |
| $H_2O$ | 1.53 | 1.51 | 1.52 |
| $B_2O_3$ | 5.21 | 5.53 | 5.37 |
| | 100.33 | 100.77 | 100.56 |

The titanium is regarded as present as $Ti_2O_3$, replacing the alumina.

Combining the alumina, titanium, and iron, the following ratios are obtained:

| | | |
|---|---|---|
| $SiO_2$ | 5.94 | or 6 |
| $Al_2O_3$ | 8.00 | 8 |
| $B_2O_3$ | 1.06 | 1 |
| $H_2O$ | .96 | 1 |

The formula for dumortierite then is

$$8Al_2O_3, 1B_2O_3, 1H_2O, 6SiO_2.$$

It has not been proved that either boric acid and alumina or boric acid and hydroxyl may mutually replace each other in minerals as fluor-

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ine and hydroxyl are known to do. There is, then, no reason that the writer can see why the alumina, boric acid, and water in dumortierite should not be present in fixed quantities, and that the variations shown in analyses are not due to "isomorphous replacements," but to inaccuracy of analyses or impure material.

Having established the above formula from the analysis, let us see how closely the other analyses conform to it.

The best series of analyses is that made by Ford of mineral from three American localities. His first analyses of the Arizona material are tabulated below.

| | 1. | 2. | 3. | Average. |
|---|---|---|---|---|
| $SiO_2$ | 30.00 | 29.66 | 29.91 | 29.86 |
| $Al_2O_3$ | 63.20 | 63.74 | 63.76 | 63.56 |
| $Fe_2O$ | .23 | .23 | ..... | .23 |
| $B_2O_3$ | 5.47 | 5.06 | ..... | 5.26 |
| $H_2O$ | 1.45 | 1.38 | ..... | 1.41 |
| | ..... | ..... | ..... | 100.32 |

The ratios calculated from the average analysis give

| | | |
|---|---|---|
| $SiO_2$ | 6.29 | or $6\times1.05$ |
| $Al_2O_3$ | 7.94 | $8\times .99$ |
| $B_2O_3$ | .96 | $1\times .96$ |
| $H_2O$ | 1.00 | $1\times1.00$ |

The agreement with the proposed formula is perfect.

His second analysis, that of the California mineral, shows slight variations from the results obtained by the writer. The presence of titanium was not determined. His analysis is:

| | | Ratios. | |
|---|---|---|---|
| $SiO_2$ | 30.58 | 6.17 | or $6\times1.03$ |
| $Al_2O_3$ | 61.83 | 7.40 | $8\times .93$ |
| $Fe_2O_3$ | .36 | | |
| $B_2O_3$ | 5.93 | 1.04 | $1\times1.04$ |
| $H_2O$ | 2.14 | 1.45 | $1\times1.45$ |
| | 100.84 | | |

The ratios agree well with the new formula except for the water content. Remembering, however, that the amount of water present is very small and that a difference of 0.10 per cent. would make a large difference in the ratios; that Ford determined his water by igniting the mineral with lime, thus not weighing the water directly; and that the writer obtained only 1.52 per cent on the same mineral from

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the same locality, it seems much preferable to regard the determination of the water in Ford's analysis as too high rather than to attempt an explanation of it by the assumption of "isomorphous replacement, etc."

Of the third analysis by Ford of the New York mineral, he says: "It is fully realized that the results are not to be looked upon as being as exact as those of the other analyses."

His analysis is:

| | | Ratios. | |
|---|---|---|---|
| $SiO_2$ | 31.24 | 6.23 or $6\times1.04$ | |
| $Al_2O_3$ | 61.26 | 7.23 | $8\times .90$ |
| $Fe_2O_3$ | .10 | | |
| $B_2O_3$ | 6.14 | 1.06 | $1\times1.06$ |
| $H_2O$ | 2.09 | 1.40 | $1\times1.40$ |
| | 100.83 | | |

Assuming that his water content is somewhat high, the ratios agree well with the new formula.

This concludes the list of analyses of dumortierite which were made on pure material and with due knowledge of what was to be determined. A number of other analyses will now be given, which serve in a general way for the determination of the composition of the mineral, but can not be relied on for exact results.

One, which has heretofore not been published, was made by the writer on the Washington dumortierite. About 200 grams of the rock was powdered, and by repeated separation with heavy solutions about 4 grams of dumortierite were obtained. The sample was by no means pure. It was found impossible to remove all the andalusite, an unknown but small amount remaining. It was found during the course of the analysis that the samples also contained some titanite (leucoxene) and a very small amount of pyrite. The analysis was made with all the care possible, and the following results were obtained:

| | | Ratios after deducting titanite. | |
|---|---|---|---|
| $SiO_2$ | 28.51 | 5.97 or $6\times0.99$ | |
| $Al_2O_3$ | 59.75 | 7.80 | $8\times .97$ |
| $Fe_2O_3$ | 2.48 | | |
| $TiO_2$ | .95 | | |
| $H_2O$ | 2.12 | 1.53 | $1\times1.53$ |
| $B_2O_3$ | 5.54 | 1.03 | $1\times1.03$ |
| $CaO$ | .68 | | |
| | 100.03 | | |

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Excepting for the high-water content the analysis agrees very well with the formula. No allowance was made for the small amount of andalusite present, which would slightly alter the ratios.

The analysis by Schimpff of dumortierite from Germany is given below. Obviously it is worthless for any calculation.

| | |
|---|---|
| $SiO_2$ | 36.81 |
| $Al_2O_3$ | 57.27 |
| CaO | 1.66 |
| MgO | 1.38 |
| Ign | 1.31 |
| $B_2O_3$ | strong test |
| | 98.43 |

Of similar character is Jannasch's analysis of the Argentine mineral. The sample was probably very impure.

| | |
|---|---|
| $SiO_2$ | 35.01 |
| $B_2O_3$ | 2.51 |
| $TiO_2$ ($Ti_2O_3$?) | 1.08 |
| $Al_2O_3$ | 51.49 |
| $Fe_2O_3$ | 1.04 |
| CaO | .28 |
| MgO | .54 |
| $K_2O$ | 3.62 |
| $Na_2O$ | .96 |
| $H_2O$ | 3.02 |
| | 99.55 |
| Specific gravity | 3.255 |

There now remain the analyses of Whitfield and Riggs, of which but one is suitable for any calculation. The analyses are as follows, No. 1 being of the New York mineral, by Riggs; No. 2 of the New York, and Nos. 3 and 4 of the Arizona mineral, by Whitfield.

| | 1. | 2. | 3. | 4. |
|---|---|---|---|---|
| $SiO_2$ | 34.82 | 31.44 | 31.52 | 27.99 |
| $Al_2O_3$ | 55.30 | 68.91 | 63.66 | 64.49 |
| MgO | .57 | ..... | .52 | trace |
| $K_2O$ | 1.04 | ..... | .11 | ..... |
| $Na_2O$ | 1.76 | ..... | .37 | ..... |
| $P_2O_5$ | ..... | ..... | ..... | .20 |
| $B_2O_3$ | 4.07 | trace | 2.62 | 4.95 |
| Ign | 2.96 | ..... | 1.34 | 1.72 |
| | 100.52 | 100.33 | 100.14 | 99.35 |

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The ratios of the last analyses are

| | | |
|---|---|---|
| $SiO_2$ | 5.94 or 6 | $\times 0.99$ |
| $Al_2O_3$ | 8.09 | $8 \times 1.01$ |
| $B_2O_3$ | .80 | $1 \times .80$ |
| $H_2O$ | 1.22 | $1 \times 1.22$ |

Approximately they agree with the formula.

The only question of which there seems to be any doubt is whether the water should be 1 or 1½ molecules. As, however, the best analyses show but 1 molecule and their evidence is considered as of much more value than a larger number of inferior analyses, there is no question in the writer's mind but that the formula for dumortierite is

$$8Al_2O_3,\ 1B_2O_3,\ 1H_2O,\ 6SiO_2.$$

This may be written

$$(SiO_4)_3Al(AlO)_7(BO)H,$$

which is the same as the formula given by Groth except that for (BO) he puts (AlO). His formula is $(SiO_4)_3Al(AlO)_8H$.

This formula may be written in the following form:

$$Al\begin{cases} SiO_4\equiv(AlO)_3 \\ SiO_4\equiv(AlO)_3 \\ SiO_4-AlO \\ \quad\ \backslash BO \\ \quad\ \backslash H \end{cases}$$

This formula is similar to that of andalusite, which is written

$$Al\begin{cases} SiO_4\equiv Al \\ SiO_4\equiv Al \\ SiO_4\equiv(AlO)_3 \end{cases}$$

Dumortierite alters to muscovite. The change can be very well shown by these formulæ, and seems to be entirely in accordance with the group of minerals to which it is related.

Dumortierite. Muscovite.

$$Al\begin{cases} SiO_4\equiv(AlO)_3 \\ SiO_4\equiv(AlO)_3 \\ SiO_4-AlO \\ \quad\ \backslash BO \\ \quad\ \backslash H \end{cases} = Al\begin{cases} SiO_4\equiv Al \\ SiO_4\equiv Al \\ SiO_4-K \\ \quad\ \backslash H_2 \end{cases} + \text{alumina and boric acid set free.}$$

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# MINERALOGICAL NOTES.

By W. T. SCHALLER.

## 1. HALLOYSITE.

The pink clay occurring at Branchville, Conn., has been shown[a] to be montmorillonite, while that occurring at Norway, Me., has proved[b] to be cimolite. That from the lepidolite mine near Pala, San Diego County, Cal., differs from both of the New England clays, being comparable with halloysite.

At Pala the halloysite occurs in large seams, often several inches thick, and many feet in length. The clay is somewhat moist, but quickly dries to a crumbling mass when taken out of the mine. In color it is rather deeper pink than the Norway cimolite and occasionally is somewhat translucent. It readily crumbles to a fine powder when placed in water. The material analyzed had been drying in the air for over three months.

The results of analysis are shown below.

| | |
|---|---|
| $SiO_2$ | 43.62 |
| $Al_2O_3$ | 35.55 |
| $Fe_2O_3$ | .21 |
| MnO | .26 |
| CaO | 1.02 |
| MgO | .19 |
| $Li_2O$ | .23 |
| $Na_2O$ | .19 |
| $K_2O$ | .03 |
| $H_2O$ (107°) | 6.63 |
| $H_2O$ (above 107°) | 12.25 |
| $TiO_2$ | none |
| | 100.18 |

The iron was determined as $Fe_2O_3$, FeO not being tested for. The analysis agrees well with the formula

$$H_4Al_2Si_2O_9+H_2O.$$

[a] Am. Jour. Sci., vol. 20, 1880, p. 283. [b] Ibid., 32, 1886, p. 355.



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## 2. AMBLYGONITE.

The occurrence of amblygonite at the lepidolite mine at Pala, Cal., has already been noticed, and a somewhat fuller description of the mineral is here given. A large deposit has been uncovered, and the indications seem to show that it is merely a small part of an extensive body of massive amblygonite. The mineral usually occurs pure; very rarely small amounts of lepidolite are present with it. Frequently broad cleavage faces with irregular outlines can be seen. The color is white and in thin pieces the mineral is translucent. It fuses easily, coloring the flame red, and in powder is difficultly decomposed by sulphuric acid.

An analysis of a specimen kindly presented by Mr. G. F. Kunz gave the writer the following results:

| | |
|---|---|
| $P_2O_5$ | 48.83 |
| $Al_2O_3$ | 33.70 |
| $Fe_2O_3$ | .12 |
| MnO | .09 |
| MgO | .31 |
| $Li_2O$ | 9.88 |
| $Na_2O$ | .14 |
| $H_2O$ | 5.95 |
| F | 2.29 |
| $TiO_2$ | none |
| | 101.31 |
| Less O | .96 |
| | 100.35 |

Regarding fluorine and hydroxyl as isomorphous, in the specimen analyzed the latter greatly predominates over the fluorine. The water was determined by igniting the mineral with lead oxide, previously heated nearly to fusion. Three determinations gave the loss of weight, due to the escape of water, as 5.89, 6.01, 5.95 per cent. The loss of the mineral on ignition was 8.03 per cent, equaling the sum of the water and fluorine content.

## 3. BOOTHITE.

A specimen of a pale-blue copper sulphate was collected at the copper mine near Campo Seco, Calaveras County, Cal., by Mr. James Wise and kindly presented to the writer for investigation. The pale-blue color suggested that the mineral might be boothite instead of the more frequently occurring chalcanthite. The results of a chemical analysis have shown that the mineral is boothite, thus affording a second locality for this interesting mineral. Careful quantitative determinations of hydrous copper sulphates will probably show that the heptahydrate is not so rare as may be supposed.

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The mineral from Campo Seco occurs massive, showing no crystalline structure. The average of several determinations afforded the results shown below.

| | | Ratio. |
|---|---|---|
| CuO | 26.13 | 1.00 |
| FeO | .81 | .03 |
| MgO | .64 | .05 |
| $SO_3$ | 27.25 | 1.04 |
| $H_2O$ (110°) | 36.76 } 41.67 | 6.22 } 7.06 |
| $H_2O$ (above 110°) | 4.91 } | .84 } |
| Insol | 3.96 | ..... |
| | 100.46 | ..... |

Formula, $CuSO_4.H_2O+6H_2O$.

A careful determination of the specific gravity of the mineral gave (21° C.) 1.944. This being much lower than the value obtained (2.1) on the boothite from Leona Heights, a redetermination of the latter was made on purer material collected since the publication of the first results.[a] This gave as an average value the figure (22° C.) 1.935. The average of these two determinations, or 1.94, is probably very near the true value for the specific gravity of boothite.

## 4. PISANITE.

A small specimen of massive pisanite from Gonzales, Monterey County, Cal., was analyzed some time ago and the results are here presented. The quantity of material available for analysis was very small and the determinations do not claim any great accuracy. About 6 per cent of insoluble matter has been deducted and the results recalculated to 100 per cent.

| | | Ratio. |
|---|---|---|
| CuO | 7.56 | 0.27 } 0.89 |
| FeO | 15.85 | .72 } |
| $SO_3$ | 30.74 | 1.08 |
| $H_2O$ | 45.85 | 7.18 |
| | 100.00 | ..... |

The analysis approximates to the formula $CuO.2FeO.3SO_3.21H_2O$.

[a] Schaller, W. T., Minerals from Leona Heights, Alameda County, Cal.: Bull. Dept. Geol. Univ. Cal., vol. 3, No. 7.

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In the following table all available analyses of pisanite are tabulated, and one can readily see that there is no definite ratio between the copper and iron. The formula is then written $(Cu,Fe)SO_4.7H_2O$, pisanite being an isomorphous mixture of melanterite and boothite. All the analyses are calculated to 100 per cent.[a]

| | No. 1. | No. 2. | No. 3. | No. 4. | No. 5. | No. 6. |
|---|---|---|---|---|---|---|
| CuO | ..... | 7.56 | 9.17 | 10.07 | 12.61 | 15.52 |
| FeO | 25.86 | 15.85 | 16.37 | (16.15) | 14.14 | 12.14 |
| $SO_3$ | 28.80 | 30.74 | 29.00 | 28.84 | 28.44 | 27.82 |
| $H_2O$ | 45.34 | 45.85 | 45.46 | (44.94) | 44.81 | 44.52 |
| | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

| | No. 7. | No. 8. | No. 9. | No. 10. | No. 11. |
|---|---|---|---|---|---|
| CuO | 15.56 | 17.45 | 17.64 | 18.81 | 27.85 |
| FeO | 10.98 | 10.18 | 9.62 | 8.51 | ..... |
| $SO_3$ | 29.90 | 28.43 | 28.27 | 27.93 | 28.02 |
| $H_2O$ | 43.56 | 43.94 | 44.47 | 44.75 | 44.13 |
| | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

## 5. GYROLITE.

In the same rock and but about 50 feet distant from the place where the pectolite[b] and datolite occur, at Fort Point, San Francisco, Cal., were a number of veins of a pearly massive zeolite, which analysis showed to be gyrolite. The veins, ranging from microscopic size to a thickness of nearly a centimeter, occur in a dark basic igneous rock, probably a basalt. The gyrolite has replaced the rock and grown outward from both sides of the vein, forming a contact line in the middle where the two parts join. The mineral is grouped in spherical and also in massive platy or plumose aggregates. It is at times associated with apophyllite, but usually occurs pure. Its color on the fresh fracture is white, while on the weathered surface it is a brownish-yellow. It has a decided pearly luster and possesses a good cleavage.

Under the microscope, a thin section of the rock containing these veins shows that the rock has been replaced by this secondary mineral, always commencing as a minute vein, probably originating in a micro-

[a] Anal. No. 1, theoretical comp. of melanterite, $FeSO_4.7H_2O$. No. 2, Schaller, anal. quoted above; No. 3, Schaller, Bull. Dept. Geol. Univ. of Cal., vol. 3, No. 7; No. 4, Hintz, Zeit. Krys., 2, 309; No. 5, Hillebrand, Bull. U. S. Geol. Survey No. 220, p. 105; No. 6, see No. 3; No. 7, Pisani, Comptes Rendus, 1859, 48, 807; No. 8, see No 3; Nos. 9 and 10, Herz, Zeit. Krys., 26, 16; No. 11, theoretical comp. of boothite, $CuSO_4.7H_2O$.

[b] Eakle, A. S., Mineralogical notes: Bull. Dept. Geol. Univ. Cal., vol. 2, No. 10, 1901.

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scopic fissure of the rock. A multitude of these veins are present, lying in nearly parallel position and varying greatly in size. There is nothing to suggest that the gyrolite may have been derived from apophyllite. It may have been derived entirely from the igneous rock or only in part. The mineral was first deposited at the walls of the vein and from thence grew outward into the open fissure from both sides, also probably replacing the rock wall. The thin section, as well as the hand specimen, shows a decided plumose structure of the mineral. These plumose aggregates show, under crossed nicols, the black extinction cross. The interference colors are bright and vivid. Heddle[a] says of these: "The sections of orbicular gyrolite are among the most splendid of polariscopic objects, resembling a circularly opened fan, of most brilliant and abruptly contrasted colors."

The properties of the mineral are not very well known. Heddle[b] mentions some crystals resembling heulandite in form. The mineral is described as unaxial, though as a matter of fact it is biaxial, but like biotite the axial angle becomes 0° at times. Cleavage plates show the emergence of a bisectrix. The (approximate) measurement of $2E_{Na}$ gave values (on the Fort Point material) of from 0° to 25°. The sign is always negative. Heddle obtained $2E = 0° - 3°$. When there was a straight edge suggesting a possible crystal direction, the extinction was not parallel.

Dana[c] gives as the formula of the mineral $3H_2O$, $2CaO$, $3SiO_2$, while Clarke[d] gives $5H_2O$, $4CaO$, $6SiO_2$, which is the formula deduced by the writer from the following analysis of the San Francisco mineral:

| | | Ratio. |
|---|---|---|
| $SiO_2$ | 53.47 | 6.02 |
| $Al_2O_3$ | .22 | ..... |
| CaO | 32.00 | 4.02 |
| $Na_2O$ | 1.25 | |
| $H_2O$ | 13.21 | 4.99 |
| | 100.15 | ..... |

The specific gravity is 2.39. Traces of iron, magnesium, and potassium are present, while strontium, chlorine, and fluorine are absent.

[a] Heddle, M. F., On the optic properties of gyrolite: Min. Mag., vol. 9, 1890–1891, p. 391.
[b] Heddle, M. F., On the crystalline form of gyrolite: Min. Mag., vol. 8, 1888–1889, p. 272.
[c] System of Mineralogy, 6th edition, p. 566, 1892.
[d] Clarke, F. W., The constitution of the silicates: Bull. U. S. Geol. Survey No. 125, 1895, p. 81.

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The mineral is easily decomposed by hydrochloric acid. Certain analogies can be noted between heulandite and gyrolite, and from this and the properties of the mineral, as far as known, the writer believes gyrolite to be monoclinic. Heddle says in connection with some plane angles he measured on gyrolite from Scotland: "The above, as far as it goes, seems to show gyrolite to be oblique, and near heulandite in form."

The formulæ of the two minerals are also similar.

| | |
|---|---|
| Gyrolite | $6SiO_2$. 4CaO. $5H_2O$. |
| Heulandite | $6SiO_2$. $Al_2O_3$. CaO. $5H_2O$. |

## 6. APOPHYLLITE.

With the gyrolite were found a number of specimens of clear, transparent, but very minute crystals of apophyllite. These are usually less than 1 mm. thick and show only the base, prism of the second order, and the unit pyramid of the first order. Some years ago a specimen was obtained here on which the apophyllite crystals have been changed to quartz. As they proved to be infusible, a more extended investigation of them was made.

The crystals, from 1 to 3 mm. in diameter, appear cubic, with the corners truncated by small faces. Measurements of the best crystals showed that they are tetragonal and that they agree in angles with those of apophyllite. The prism faces are vertically striated and faces of the other two forms are also rarely somewhat striated.

By trial it was found that hydrochloric acid does not attack the crystals, so that the associated calcite was easily removed and pure material for analysis was obtained. The crystals are opaque, and no optical determinations could be made.

The analysis gave the following figures, showing that the crystals are now, chemically, essentially silica with various impurities:

| | |
|---|---|
| $SiO_2$ | 90.58 |
| $Al_2O_3$ | 1.58 |
| CaO | 1.87 |
| MgO | 2.20 |
| $H_2O$ | 4.32 |
| | 100.55 |

## 7. TELLURITE.

Several small crystals of tellurite were referred to the writer by Doctor Hillebrand. Their locality is the W. P. H. mine, Cripple Creek, Colo. The crystals are transparent yellow and reach a length of about 2 mm. They are thin tabular parallel to the brachypinacoid. This form is normal to a bisectrix, and the axial plane is parallel to *a* (100).

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The crystals show numerous vicinal faces, which are here not given. The forms which were established are[a]

$$b=\{010\},\ r=\{120\},\ {}^*h=\{520\},\ {}^*l=\{210\},\ p=\{111\}.$$

The angles measured are:

| | Measured. | | | | Calculated. | | | |
|---|---|---|---|---|---|---|---|---|
| | $\phi$. | | $\rho$. | | $\phi$. | | $\rho$. | |
| | ° | ′ | ° | ′ | ° | ′ | ° | ′ |
| $b$=010 | 0 | 00 | 90 | 00 | 0 | 00 | 90 | 00 |
| $r$=120 | 47 | 34 | 90 | 00 | 47 | 30 | 90 | 00 |
| $h$=520 | 79 | 30 | 90 | 00 | 79 | 37 | 90 | 00 |
| $l$=210 | 77 | 17 | 90 | 00 | 77 | 06 | 90 | 00 |
| $p$=111 | 65 | 47 | 48 | 14 | 65 | 23 | 48 | 16 |

The two new forms, $h$ and $l$, gave the following measurements:

| $h=\{520\}$. | Measured, $\phi$. | | Calculated, $\phi$. | |
|---|---|---|---|---|
| | ° | ′ | ° | ′ |
| Crystal No. 1 | 79 | 01 | 79 | 37 |
| Do | 79 | 19 | | |
| Crystal No. 2 | 79 | 14 | | |
| Crystal No. 4 | 80 | 59 | | |
| Do | 79 | 02 | | |
| Do | 79 | 26 | | |

On crystals Nos. 1 and 4 the faces are very narrow, while on crystal No. 2 they are much broader. The reflections were fairly good.

| $l=\{210\}$. | Measured, $\phi$. | | Calculated, $\phi$. | |
|---|---|---|---|---|
| | ° | ′ | ° | ′ |
| Crystal No. 3 | 77 | 21 | 77 | 06 |
| Do | 77 | 12 | | |

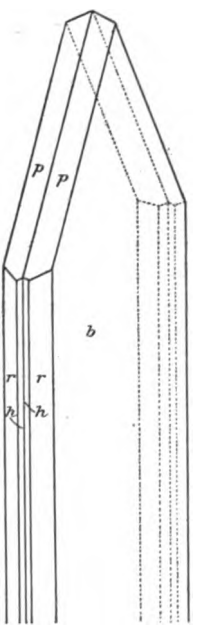


FIG. 9.—Tellurite.

The faces were both narrow and the reflections were rather poor.

It seems to the writer that the axial ratio as given by Dana should be preferred to that of Goldschmidt, who doubles both the $a$ and $c$ axes. This would make the (only) terminal form the unit pyramid,

[a] Dana's letters and indices.

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while the forms in the prism zone have as simple indices in one case as in another, as can be seen from the following table.

| | Dana. | Goldschmidt. | | Dana. | Goldschmidt. |
|---|---|---|---|---|---|
| *b* | 010 | 010 | *h* | 520 | 510 |
| *m* | 110 | 210 | *l* | 210 | 410 |
| *r* | 120 | 110 | *p* | 111 | 212 |
| *s* | 140 | 120 | | | |

## 8. PREHNITE.

A mineral from Lower California, sent by G. F. Kunz for determination, proved to be prehnite. The analysis gave the following results:

| | |
|---|---|
| $SiO_2$ | 43.48 |
| $Al_2O_3$ | 24.52 |
| $Fe_2O_3$ | .34 |
| CaO | 27.19 |
| $H_2O$ | 4.49 |
| | 100.02 |
| Specific gravity | 2.90 |

## 9. HORNBLENDE.

Coating the walls and projecting into the amygdaloidal cavities of a lava from Mono County, Cal., were noted small crystals of hornblende, tridymite, and biotite. The locality of the rock, which was kindly furnished by Mr. Maynard Bixby, of Salt Lake City, is given as 8 miles west of Bridgeport, Mono County, Cal. The hornblende and tridymite occur in sharp crystals, of which a few were measured.

Biotite occurs abundantly as small hexagonal plates, which, under the microscope, show at times a zonal banding in color, the darker being on the outside. The axial angle is very small—at times uniaxial.

The hornblende occurs as long prismatic crystals, becoming extremely acicular and hairlike at times. It is often grouped in radiating bunches and again occurs in single prisms. Their maximum thickness is about one-half millimeter, and in length they reach not over 5 mm. Under the microscope the pleochroism is in shades of brown. The maximum extinction was 15°.

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Two terminated crystals of measurable size showed the following forms: $c=\{001\}$, $b=\{010\}$, $a=\{100\}$, $m=\{110\}$, $t=\{\bar{2}01\}$, $z=\{021\}$, $i=\{\bar{1}31\}$.

| | Measured. | | | | Calculated. | | | |
|---|---|---|---|---|---|---|---|---|
| | $\phi$. | | $\rho$. | | $\phi$. | | $\rho$. | |
| | ° | ′ | ° | ′ | ° | ′ | ° | ′ |
| $c = 001$ | 90 | 25 | 14 | 57 | 90 | 00 | 14 | 58 |
| $b = 010$ | 0 | 00 | 90 | 00 | 0 | 00 | 90 | 00 |
| $a = 100$ | 90 | 14 | 90 | 00 | 90 | 00 | 90 | 00 |
| $m = 110$ | 62 | 08 | 90 | 00 | 62 | 05 | 90 | 00 |
| $t = \bar{2}01$ | 90 | 03 | 40 | 36 | 90 | 00 | 40 | 05 |
| $z = 021$ | 24 | 32 | 32 | 50 | 24 | 28 | 32 | 50 |
| $i = \bar{1}31$ | 18 | 18 | 42 | 45 | 18 | 03 | 42 | 49 |

Crystal No. 1 shows: *a*, *b*, *c*, *m*, *t*, *z*, *i*.
Crystal No. 2 shows: *a*, *b*, —, *m*, —, *z* —.

## 10. TRIDYMITE.

Small hexagonal plates of tridymite, 1 mm. in diameter and rarely larger, are rather plentiful in places. The forms present on two crystals which were partially measured are $c=\{0001\}$, $m=\{10\bar{1}0\}$, $i=\{32\bar{5}0\}$, $l=\{54\bar{9}0\}$, $r=\{30\bar{3}4\}$, $f=\}10\bar{1}2\}$. The first crystal measured was a twin.

| | Measured. | | Calculated. | |
|---|---|---|---|---|
| | ° | ′ | ° | ′ |
| $c \wedge c$ | 35 | 06 | 35 | 18 |
| $c \wedge m$ | 90 | 02 | 90 | 00 |
| $m \wedge i$ | 23 | 20 | 23 | 25 |
| $m \wedge l$ | 26 | 39 | 26 | 20 |
| $c \wedge r$ | 54 | 48 | 55 | 03 |
| $c \wedge f$ | 43 | 54 | 43 | 39 |

## 11. ZINNWALDITE.

The occurrence of this lithia mica has already been mentioned by Collier,[a] who has very kindly furnished the writer the numerous samples collected. He gives as the exact locality: On Cassiterite Creek (extension or branch of Lost River), 5 miles from the coast and 8 miles

[a] Collier, A. J., The tin deposits of the York region, Alaska: Bull. U. S. Geol. Survey No. 229, p. 20.



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east of Cape York, Alaska. It is stated to occur in a vein cutting through limestone. The bowlders showing the zinnwaldite are float, and in some of these there is a vein, about a centimeter thick, consisting almost entirely of zinnwaldite. Others show the zinnwaldite scattered through massive quartz. Cassiterite is associated with both modes of occurrence. As further associations Collier mentions fluorite, feldspar, calcite, tourmaline, topaz, pyrite, garnet, galena, wolframite, and malachite.

The zinnwaldite has a brown color, and occurs massive without any crystal boundaries. It fuses easily to a black mass, coloring the flame crimson. An incomplete quantitative analysis showed that the mineral is undoubtedly zinnwaldite. The small dikes before mentioned are bordered on one side by a rim of blackish green mica. This rim is about 1 mm. wide and is well developed only on one side of the dike, though it is present on the other side in smaller amount. Under the microscope the rim has a green and brown color and is uniaxial nearest the limestone, but the axial angle increases as the zinnwaldite is approached. In many places the two micas are intergrown. The difference in color from the green to the almost colorless zinnwaldite is very marked. The green mica is probably biotite, possibly somewhat altered to chlorite. Further description of the zinnwaldite is deferred for a later paper. Of the associated minerals, cassiterite and topaz occur in small crystals, a brief description of which follows. The association of cassiterite, topaz, and zinnwaldite is also noteworthy.

## 12. CASSITERITE.

The crystals of cassiterite vary in size, ranging from a thickness of less than 1 mm. to several cm. The large ones are opaque and black; the smaller ones are usually transparent and light brown in color, becoming nearly colorless at times. Twins are very common.

The large crystals usually show the simple combination of $a=\{100\}$, $m=\{110\}$, $e=\{011\}$, $s=\{111\}$, while the smaller ones usually are more complex. Two such small ones were measured, the first one a simple crystal, the second a twin. The forms noted are: $a=\{100\}$, $m=\{110\}$, $k=\{340\}$, $B=\{570\}$?, $r=\{230\}$, $h=\{120\}$, $e=\{011\}$, $s=\{111\}$, $f=\{231\}$, and the new prism $l=\{140\}$.

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The following are the measured angles:

| | Measured. | | | | Calculated. | | | |
|---|---|---|---|---|---|---|---|---|
| | $\phi$. | | $\rho$. | | $\phi$. | | $\rho$. | |
| | ° | ′ | ° | ′ | ° | ′ | ° | ′ |
| $a$=100 | 0 | 00 | 90 | 00 | 0 | 00 | 90 | 00 |
| $m$=110 | 45 | 00 | 90 | 00 | 45 | 00 | 90 | 00 |
| $k$=340 | 36 | 35 | 90 | 00 | 36 | 52 | 90 | 00 |
| $B$=570 | 35 | 48 | 90 | 00 | 35 | 32 | 90 | 00 |
| $r$=230 | 33 | 37 | 90 | 00 | 33 | 41 | 90 | 00 |
| $h$=120 | 26 | 30 | 90 | 00 | 26 | 34 | 90 | 00 |
| $l$=140 | 13 | 56 | 90 | 00 | 14 | 02 | 90 | 00 |
| $e$=011 | 0 | 03 | 33 | 48 | 0 | 00 | 33 | 54 |
| $s$=111 | 45 | 01 | 43 | 35 | 45 | 00 | 43 | 33 |
| $f$=231 | 33 | 46 | 67 | 39 | 33 | 41 | 67 | 35 |

The prism $l$=$\{140\}$ was noted three times as a narrow face, measurements of which gave the following values for the $\phi$ angle:

| ° | ′ |
|---|---|
| 13 | 49 |
| 13 | 19 |
| 14 | 40 |

The dominant terminal form is $\{111\}$, though $\{011\}$ becomes at times fairly large. $\{231\}$ occurs on crystal No. 1 as minute faces and also as long, narrow line faces.

## 13. TOPAZ.

Two small crystals, about 2 mm. long, which were measured, showed the following forms:[a] $b$=$\{010\}$, $m$=$\{110\}$, $l$=$\{120\}$, $\pi$=$\{250\}$, $g$=$\{130\}$, $y$=$\{021\}$, $f$=$\{011\}$, $u$=$\{112\}$, $s$=$\{335\}$, $o$=$\{111\}$. The crystals were rounded and broken and gave, on the whole, rather poor signals. The measurements serve, however, to determine the forms.

| | Measured. | | | | Calculated. | | | |
|---|---|---|---|---|---|---|---|---|
| | $\phi$. | | $\rho$. | | $\phi$. | | $\rho$. | |
| | ° | ′ | ° | ′ | ° | ′ | ° | ′ |
| $b$=010 | 1 | 36 | 90 | 00 | 0 | 00 | 90 | 00 |
| $m$=110 | 61 | 59 | 90 | 00 | 62 | 08 | 90 | 00 |
| $l$=120 | 43 | 28 | 90 | 00 | 43 | 25 | 90 | 00 |
| $\pi$=250 | 37 | 00 | 90 | 00 | 37 | 07 | 90 | 00 |
| $g$=130 | 32 | 26 | 90 | 00 | 32 | 14 | 90 | 00 |
| $y$=021 | 0 | 38 | 61 | 44 | 0 | 00 | 62 | 20 |
| $f$=011 | 0 | 38 | 44 | 24 | 0 | 00 | 43 | 39 |
| $u$=112 | 61 | 56 | 45 | 39 | 62 | 08 | 45 | 35 |
| $s$=335 | 61 | 42 | 50 | 31 | 62 | 08 | 50 | 46 |
| $o$=111 | 63 | 10 | 63 | 00 | 62 | 08 | 63 | 54 |

The only terminal form on crystal No. 1 is $u$=$\{112\}$.

[a] Goldschmidt's orientation, chosen in Winkeltabellen.

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## 14. BOURNONITE.

An analysis of massive bournonite from Bogg's mine, Big Bug district, Yavapai County, Ariz., furnished for analysis by Prof. C. Palache, yielded the figures given below.

| | |
|---|---|
| S | 20.04 |
| As | 2.81 |
| Sb | 18.99 |
| Pb | 40.21 |
| Cu | 15.12 |
| Fe | .35 |
| Zn | .35 |
| Mn | trace |
| Insoluble | 1.67 |
| | 99.54 |

## 15. ANHYDRITE.

A deposit of crystallized anhydrite occurs in Texas, the exact locality of which is not known. The crystals are small, reaching a maximum of 1 mm. in length, and are tabular parallel to the macropinacoid. The base is present as a long, narrow face. The clinopinacoid is probably present, but the zone of brachydomes is very rounded and striated, no sharp faces occurring in this zone. Under the microscope the crystals show that the axial plane is parallel to $b=\{010\}$ and the acute bisectrix is normal to $a=\{100\}$. The interference figure is about as large as that of muscovite and is positive. An analysis was made of the mineral, to leave no doubt as to its identity.

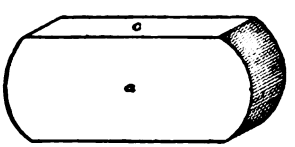


FIG. 10.—Anhydrite.

| | |
|---|---|
| CaO | 41.01 |
| $SO_3$ | 58.87 |
| Ign | .22 |
| Insoluble | .06 |
| | 100.16 |

## 16. GLAUCODOT.

A sample of cobalt ore from the Standard Consolidated gold mine, Sumpter, Oreg., consists of glaucodot, with pyrite and perhaps other sulphides, in a dark silicate rock. Imperfect crystals are abundant, though they usually show but one or two faces. Much of the ore is massive, and it is practically impossible to determine whether it is all glaucodot or in part cobaltite. One crystal was measured. The small crystal (about 1 mm. long) is orthorhombic, and shows the following forms: $m=\{110\}$, $b=\{010\}$, $e=\{101\}$, and a very much striated brachydome zone in which the following forms are probably present: $\{014\}$, $\{013\}$, $\{012\}$.

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The following are the angles obtained:

| | Measured. | | | | Calculated. | | | |
|---|---|---|---|---|---|---|---|---|
| | $\phi$. | | $\rho$. | | $\phi$. | | $\rho$. | |
| | ° | ′ | ° | ′ | ° | ′ | ° | ′ |
| $b$ =010 | 0 | 34 | 90 | 00 | 0 | 00 | 90 | 00 |
| $m$=110 | 56 | 10 | 90 | 00 | 55 | 34 | 90 | 00 |
| $e$ =101 | 90 | 20 | 60 | 22 | 90 | 00 | 60 | 04 |
| $r$ =014 | 0 | 34 | 15 | 33 | 0 | 00 | 16 | 34 |
| $q$ =013 | 0 | 34 | 22 | 00 | 0 | 00 | 21 | 39 |
| $s$ =012 | 0 | 34 | 29 | 00 | 0 | 00 | 30 | 46 |

Many other signals between these were seen in the striated brachydome zone, but they probably belong to no definite face.

The analysis gave the following results:

| | | Ratio. |
|---|---|---|
| As | 39.84 | 0.94 |
| S | 18.46 | 1.04 |
| Fe | 12.45 | 1.02 |
| Co | 20.23 | |
| Insol | 9.38 | ..... |
| | 100.36 | ..... |

Nickel and antimony were not determined, though they were shown not to be present in any quantity. The ratio of the cobalt to iron is 31:20 or 3:2, so that the formula may be written

$$Co_3 Fe_2 As_5 S_5,$$

instead of

$$R\ As\ S,\ R=(Co, Fe).$$

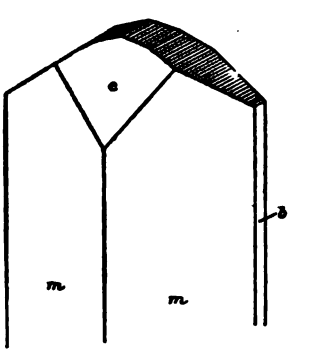


FIG. 11.—Glaucodot.

### 17. PYRITE.

A small group of pyrite crystals from Spanish Peaks, Colo., kindly presented to the writer by Mr. R. Sargent, showed, on examination, a rich combination of forms, especially in the pyritohedral zone. The faces are for the most part not striated and give excellent reflections. In size the crystals reach a maximum of about one-half centimeter in diameter. They were so closely crowded together that only a small portion of each crystal was developed; consequently, when the group was broken, a few fragments showed only one or two zones of faces.

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Twenty-five forms are present on the twelve crystals measured. They are:

| | | | |
|---|---|---|---|
| $c$ =100 | $\alpha$=470 | $\delta$ =450 | $q$ =112 |
| $A$=1.10.0 | $h$ =350 | $\xi$ =560 | $o$ =111 |
| $\mathfrak{b}$ =180 | $C$=580 | $\gamma$=670 | $u$ =221 |
| $f$ =140 | $D$=570 | $d$ =110 | $x$ =123 |
| $a$ =130 | $i$ =340 | $K$=114 | $\psi$=124 |
| $e$ =120 | $E$=790 | $m$=113 | $\omega$=134 |
| $B$=590 | | | |

The average of the angles measured with the calculated angles are shown in the following table:

| No. | Letter. | Symbol. | Measured. | | | | Calculated. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $\phi$. | | $\rho$. | | $\phi$. | | $\rho$. | |
| | | | ° | ′ | ° | ′ | ° | ′ | ° | ′ |
| 1 | $c$ | 100 | 90 | 00 | 90 | 00 | 90 | 00 | 90 | 00 |
| 2 | $A$ | 1.10.0 | 5 | 49 | 90 | 00 | 5 | 43 | 90 | 00 |
| 3 | $\mathfrak{b}$ | 180 | 7 | 08 | 90 | 00 | 7 | 08 | 90 | 00 |
| 4 | $f$ | 140 | 14 | 03 | 90 | 00 | 14 | 02 | 90 | 00 |
| 5 | $a$ | 130 | 19 | 06 | 90 | 00 | 18 | 26 | 90 | 00 |
| 6 | $e$ | 120 | 26 | 34 | 90 | 00 | 26 | 34 | 90 | 00 |
| 7 | $B$ | 590 | 28 | 59 | 90 | 00 | 29 | 03 | 90 | 00 |
| 8 | $\alpha$ | 470 | 29 | 30 | 90 | 00 | 29 | 45 | 90 | 00 |
| 9 | $h$ | 350 | 31 | 04 | 90 | 00 | 30 | 58 | 90 | 00 |
| 10 | $C$ | 580 | 31 | 59 | 90 | 00 | 32 | 00 | 90 | 00 |
| 11 | $D$ | 570 | 35 | 17 | 90 | 00 | 35 | 32 | 90 | 00 |
| 12 | $i$ | 340 | 36 | 52 | 90 | 00 | 36 | 52 | 90 | 00 |
| 13 | $E$ | 790 | 37 | 47 | 90 | 00 | 37 | 52 | 90 | 00 |
| 14 | $\delta$ | 450 | 38 | 39 | 90 | 00 | 38 | 39 | 90 | 00 |
| 15 | $\xi$ | 560 | 39 | 48 | 90 | 00 | 39 | 48 | 90 | 00 |
| 16 | $\gamma$ | 670 | 40 | 36 | 90 | 00 | 40 | 36 | 90 | 00 |
| 17 | $d$ | 110 | 45 | 00 | 90 | 00 | 45 | 00 | 90 | 00 |
| 18 | $K$ | 114 | 45 | 00 | 19 | 25 | 45 | 00 | 19 | 28 |
| 19 | $m$ | 131 | 18 | 33 | 72 | 45 | 18 | 26 | 72 | 27 |
| 20 | $q$ | 112 | 26 | 34 | 65 | 54 | 26 | 34 | 65 | 54 |
| | | 121 | 44 | 59 | 35 | 15 | 45 | 00 | 35 | 16 |
| 21 | $o$ | 111 | 45 | 00 | 54 | 44 | 45 | 00 | 54 | 44 |
| 22 | $u$ | 122 | 45 | 00 | 70 | 31 | 45 | 00 | 70 | 31 |
| | | 221 | 26 | 34 | 48 | 13 | 26 | 34 | 48 | 11 |
| 23 | $x$ | 123 | 26 | 35 | 36 | 40 | 26 | 34 | 36 | 42 |
| | | 132 | 18 | 31 | 57 | 40 | 18 | 26 | 57 | 41 |
| | | 231 | 33 | 42 | 74 | 30 | 33 | 41 | 74 | 30 |
| 24 | $\psi$ | 124 | 26 | 20 | 28 | 40 | 26 | 34 | 29 | 12 |
| 25 | $\omega$ | 134 | 18 | 18 | 39 | 37 | 18 | 26 | 38 | 19 |

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Of the pyritohedrons $i$ is the dominant form and is always well developed in large broad faces. $e$, $\delta$, $\xi$, $\gamma$ occur quite frequently as smaller faces, while $\mathfrak{b}$, $f$, $a$, $\alpha$, $h$, are rarely present as very narrow faces. $c$ is also narrow but never striated, always giving perfect reflections. The dodecahedron, $d$, is usually somewhat uneven. The octahedron, $o$, and $q$, $u$, and $x$ occur commonly, while $k$, $m$, $\psi$, $\omega$ were observed but once each.

## 18. VANADINITE.

A specimen of vanadinite, doubtless from Yuma County, Ariz., shows a few crystals that possess a large number of forms. The crystals are 3 mm. long and 2 mm. thick, and present the usual appearance and habit of vanadinite. The zone $c\ m$ is, however, very rich in forms. A number of vicinal forms were encountered that seem characteristic of the particular specimen. Sometimes the crystals are broken, or an apparently simple crystal may be composed of several ones not strictly in parallel position. In such cases, each zone $c\ m$ was carefully adjusted by itself and the angles were measured. A continuous line of signals was practically never encountered, each face being distinct and giving a sharp signal.

The forms observed are quoted below.

Known forms:
$c=0001$
$a=10\bar{1}0$
$b=11\bar{2}0$
$h=21\bar{3}0$
$g=31\bar{4}0$
$\sigma=10\bar{1}3$
$r=10\bar{1}2$
$x=10\bar{1}1$
$\delta=50\bar{5}4$
$\gamma=40\bar{4}3$
$\alpha=30\bar{3}2$
$\beta=50\bar{5}3$
$y=20\bar{2}1$
$q=50\bar{5}2$

Known forms—Continued.
$z=30\bar{3}1$
$\pi=40\bar{4}1$
$s=11\bar{2}1$
$v=11\bar{2}2$
$i=21\bar{3}1$
$\xi=41\bar{5}4$
$l=32\bar{5}2$

New forms:
$d=53\bar{8}0$
$k=30\bar{3}4$
$o=70\bar{7}6$
$u=70\bar{7}5$
$A=70\bar{7}4$
$H=70\bar{7}2$

New forms—Continued.
$K=11.0.\bar{1}\bar{1}.3$
$L=10.0.\bar{1}0.1$

Vicinal forms:
$26.0.\bar{2}6.25$
$43.0.\bar{4}3.40$
$19.0.\bar{1}9.10$
$15.0.\bar{1}5.7$

Doubtful forms:
$n=11.0.\bar{1}\bar{1}.10$
$B=90\bar{9}5$
$D=90\bar{9}4$
E$=80\bar{8}3$
G$=10.0.\bar{1}0.3$
F$=11.0.\bar{1}\bar{1}.4$

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The measured and calculated angles for all these forms are:

| No. | Letter. | Symbol. | Measured. | | | | Calculated. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Miller. | $\phi$. | | $\rho$. | | $\phi$. | | $\rho$. | |
| | | | ° | ′ | ° | ′ | ° | ′ | ° | ′ |
| 1 | *c* | 0001 | ---------- | | 0 | 00 | ---------- | | 0 | 00 |
| 2 | *a* | $10\bar{1}0$ | 0 | 00 | 90 | 00 | 0 | 00 | 90 | 00 |
| 3 | *b* | $11\bar{2}0$ | 30 | 00 | 90 | 00 | 30 | 00 | 90 | 00 |
| 4 | *h* | $21\bar{3}0$ | 19 | 09 | 90 | 00 | 19 | 06 | 90 | 00 |
| 5 | *g* | $31\bar{4}0$ | 13 | 54 | 90 | 00 | 13 | 54 | 90 | 00 |
| 6 | *d* | $53\bar{8}0$ | 21 | 34 | 90 | 00 | 21 | 47 | 90 | 00 |
| 7 | *σ* | $10\bar{1}3$ | 0 | 00 | 15 | 23 | 0 | 00 | 15 | 20 |
| 8 | *r* | $10\bar{1}2$ | 0 | 00 | 22 | 22 | 0 | 00 | 22 | 21 |
| 9 | *k* | $30\bar{3}4$ | 0 | 00 | 31 | 44 | 0 | 00 | 31 | 40 |
| 10 | *x* | $10\bar{1}1$ | 0 | 00 | 39 | 29 | 0 | 00 | 39 | 26 |
| 11 | — | $26.0.\bar{2}\bar{6}.25$ | 0 | 00 | 40 | 26 | 0 | 00 | 40 | 32 |
| 12 | — | $43.0.\bar{4}\bar{3}.40$ | 0 | 00 | 41 | 29 | 0 | 00 | 41 | 29 |
| 13 | *n* | $11.0.\bar{1}\bar{1}.10$ | 0 | 00 | 42 | 16 | 0 | 00 | 42 | 08 |
| 14 | *o* | $70\bar{7}6$ | 0 | 00 | 43 | 54 | 0 | 00 | 43 | 49 |
| 15 | *δ* | $50\bar{5}4$ | 0 | 00 | 45 | 47 | 0 | 00 | 45 | 47 |
| 16 | *γ* | $40\bar{4}3$ | 0 | 00 | 47 | 37 | 0 | 00 | 47 | 38 |
| 17 | *u* | $70\bar{7}5$ | 0 | 00 | 49 | 05 | 0 | 00 | 49 | 01 |
| 18 | *α* | $30\bar{3}2$ | 0 | 00 | 50 | 53 | 0 | 00 | 50 | 58 |
| 19 | *β* | $50\bar{5}3$ | 0 | 00 | 54 | 02 | 0 | 00 | 53 | 53 |
| 20 | *A* | $70\bar{7}4$ | 0 | 00 | 55 | 13 | 0 | 00 | 55 | 12 |
| 21 | *B* | $90\bar{9}5$ | 0 | 00 | 56 | 09 | 0 | 00 | 55 | 57 |
| 22 | — | $19.0.\bar{1}\bar{9}.10$ | 0 | 00 | 57 | 24 | 0 | 00 | 57 | 23 |
| 23 | *y* | $20\bar{2}1$ | 0 | 00 | 58 | 42 | 0 | 00 | 58 | 42 |
| 24 | — | $15.0.\bar{1}\bar{5}.7$ | 0 | 00 | 60 | 25 | 0 | 00 | 60 | 25 |
| 25 | *D* | $90\bar{9}4$ | 0 | 00 | 61 | 42 | 0 | 00 | 61 | 37 |
| 26 | *q* | $50\bar{5}2$ | 0 | 00 | 63 | 43 | 0 | 00 | 64 | 03 |
| 27 | *E* | $80\bar{8}3$ | 0 | 00 | 65 | 30 | 0 | 00 | 65 | 29 |
| 28 | *F* | $11.0.\bar{1}\bar{1}.4$ | 0 | 00 | 66 | 10 | 0 | 00 | 66 | 09 |
| 29 | *ζ* | $30\bar{3}1$ | 0 | 00 | 67 | 52 | 0 | 00 | 67 | 56 |
| 30 | *G* | $10.0.\bar{1}\bar{0}.3$ | 0 | 00 | 69 | 53 | 0 | 00 | 69 | 57 |
| 31 | *H* | $70\bar{7}2$ | 0 | 00 | 70 | 57 | 0 | 00 | 70 | 50 |
| 32 | *K* | $11.0.\bar{1}\bar{1}.3$ | 0 | 00 | 71 | 38 | 0 | 00 | 71 | 39 |
| 33 | *π* | $40\bar{4}1$ | 0 | 00 | 73 | 04 | 0 | 00 | 73 | 05 |
| 34 | *L* | $10.0.\bar{1}\bar{0}.1$ | 0 | 00 | 83 | 09 | 0 | 00 | 83 | 04 |
| 35 | *s* | $11\bar{2}1$ | 30 | 15 | 54 | 40 | 30 | 00 | 54 | 55 |
| 36 | *r* | $11\bar{2}2$ | 29 | 54 | 35 | 22 | 30 | 00 | 35 | 27 |
| 37 | *i* | $21\bar{3}1$ | 19 | 02 | 65 | 11 | 19 | 06 | 65 | 19 |
| 38 | *ξ* | $41\bar{5}4$ | 10 | 56 | 41 | 49 | 10 | 53 | 43 | 17 |
| 39 | *l* | $32\bar{5}2$ | 20 | 38 | 60 | 03 | 23 | 25 | 60 | 50 |

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Following is a short description of the new forms, the $\rho$ angle only being given for the pyramids, $\phi$ being 0° 00′.

$d=\{5\bar{3}80\}$: Four faces of this new prism were noted, always as line faces.

| | ° | ′ | | ° | ′ |
|---|---|---|---|---|---|
| Meas. $\phi$.... | 21 | 20 | Calc. $\phi$.... | 21 | 47 |
| | | 33 | | | |
| | | 37 | | | |
| | | 48 | | | |

$k=\{30\bar{3}4\}$: Only two faces of this form are present, both on the same crystal. The faces, though narrow, are broader than many of the others, and gave fairly good reflections.

| | ° | ′ | | ° | ′ |
|---|---|---|---|---|---|
| Meas.... | 31 | 45 | Calc.... | 31 | 40 |
| | | 43 | | | |

$\{26.0.\bar{2}6.25\}$: This and the following form are doubtless vicinal to $\{10\bar{1}1\}$, though they both occur a number of times. This one is present on four crystals, and the measurements show the following values:

| | ° | ′ | | ° | ′ | |
|---|---|---|---|---|---|---|
| Meas.... | 40 | 24 | Calc.... | 40 | 32 | |
| | | 26 | Calc. for $\{10\bar{1}1\}$ | 39° | 26′ | |
| | | 36 | | | | |
| | | 25 | | | | |
| | | 19 | | | | |
| | | 25 | | | | |

$\{43.0.\bar{4}3.40\}$: This vicinal form is present on three crystals and occurs nine times. The faces are small and the reflections fair.

| | ° | ′ | | ° | ′ |
|---|---|---|---|---|---|
| Meas.... | 41 | 24 | Calc.... | 41 | 29 |
| | | 30 | Calc. for $\{10\bar{1}1\}$, 39° 26′. | | |
| | | 32 | | | |
| | | 16 | | | |
| | | 24 | | | |
| | | 35 | | | |
| | | 26 | | | |
| | | 35 | | | |
| | | 37 | | | |

$n=\{11.0.\bar{1}\bar{1}.10\}$: This form occurs on two crystals. The faces are narrow and the reflections but fair.

| | ° | ′ | | ° | ′ |
|---|---|---|---|---|---|
| Meas.... | 42 | 24 | Calc.... | 42 | 08 |
| | | 20 | | | |
| | | 04 | | | |

The form can be only classed as doubtful.

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$o=\{70\bar{7}6\}$: Occurring on three crystals, the following angles were measured:

| | ° | ′ | | ° | ′ |
|---|---|---|---|---|---|
| Meas.... | 43 | 24 | Calc.... | 43 | 49 |
| | | 53 | | | |
| | 44 | 06 | | | |
| | | 14 | | | |

$u=\{70\bar{7}5\}$: The reflections from the very narrow faces of this form were poor.

| | ° | ′ | | ° | ′ |
|---|---|---|---|---|---|
| Meas.... | 49 | 17 | Calc.... | 49 | 01 |
| | | 16 | | | |
| | 48 | 42 | | | |

$A=\{7074\}$: This is the most prominent of the new forms, and occurs ten times as (relatively) broad faces on four crystals. The reflections were usually fairly good.

| | ° | ′ | | ° | ′ |
|---|---|---|---|---|---|
| Meas.... | 54 | 52 | Calc.... | 55 | 12 |
| | | 49 | | | |
| | | 52 | | | |
| | | 48 | | | |
| | 55 | 35 | | | |
| | | 11 | | | |
| | | 38 | | | |
| | | 12 | | | |
| | | 24 | | | |
| | | 17 | | | |

$B=\{90\bar{9}5\}$: A very doubtful form, present as very narrow faces giving poor reflections.

| | ° | ′ | | ° | ′ |
|---|---|---|---|---|---|
| Meas.... | 56 | 18 | Calc.... | 55 | 57 |
| | | 05 | | | |

$\{19.0.\bar{1}\bar{9}.10\}$: Another vicinal form, doubtless vicinal to $\{20\bar{2}1\}$.

| | ° | ′ | | ° | ′ |
|---|---|---|---|---|---|
| Meas.... | 56 | 59 | Calc.... | 57 | 23 |
| | 57 | 18 | | | |
| | | 18 | Calc. for $\{20\bar{2}1\}$, 58° 42′ | | |
| | | 30 | | | |
| | | 19 | | | |

$C=\{15.0.\bar{1}\bar{5}.7\}$: Another vicinal form occurring on three crystals.

| | ° | ′ | | ° | ′ |
|---|---|---|---|---|---|
| Meas.... | 60 | 13 | Calc.... | 60 | 25 |
| | | 38 | | | |
| | | 24 | | | |

$D=\{90\bar{9}4\}$: A doubtful form present on one crystal.

| | ° | ′ | | ° | ′ |
|---|---|---|---|---|---|
| Meas.... | 61 | 53 | Calc.... | 61 | 37 |
| | | 30 | | | |

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$E=\{80\bar{8}3\}$: A very doubtful form.

| | ° | ′ | | ° | ′ |
|---|---|---|---|---|---|
| Meas.... | 65 | 30 | Calc.... | 65 | 29 |
| | 65 | | | | |

$F=\{11.0.\bar{1}\bar{1}.4\}$: A doubtful form.

| | ° | ′ | | ° | ′ |
|---|---|---|---|---|---|
| Meas.... | 66 | 01 | Calc.... | 66 | 09 |
| | | 19 | | | |

$G=\{10.0.\bar{1}\bar{0}.3\}$: A doubtful form.

| | ° | ′ | | ° | ′ |
|---|---|---|---|---|---|
| Meas.... | 69 | 54 | Calc.... | 69 | 57 |

$H=\{70\bar{7}2\}$: Though occurring but once as a small face, it gave a fairly good reflection.

| | ° | ′ | | ° | ′ |
|---|---|---|---|---|---|
| Meas.... | 70 | 57 | Calc.... | 70 | 50 |

$K=\{11.0.\bar{1}\bar{1}.3\}$: Two faces of this form were noted.

| | ° | ′ | | ° | ′ |
|---|---|---|---|---|---|
| Meas.... | 71 | 41 | Calc.... | 71 | 39 |
| | | 35 | | | |

$L=\{10.0.\bar{1}\bar{0}.1\}$: Two faces of this form are present on one crystal.

| | ° | ′ | | ° | ′ |
|---|---|---|---|---|---|
| Meas.... | 82 | 56 | Calc.... | 83 | 04 |
| | 83 | 21 | | | |

The average value obtained for $p_0$ is 0.8223.

## 19. GLOBULAR LEPIDOLITE.

Text-books on mineralogy do not mention the globular form for the lithia-mica lepidolite. Such globular forms have long been known for muscovite, and in fact are by no means uncommon for that species. While studying the literature of lepidolite in general two occasions were noted in which globular lepidolite was spoken of.

One was by vom Rath[a] in describing the lithia deposits of the island of Elba. On page 649 he says: "Zuweilen sind die (lepidolite) Blätter zu Kugeln gruppirt"—at times the (lepidolite) plates are grouped in spheres (=globular).

The second mention was found in Hamlin's[b] book on Mount Mica, Paris, Me., in which he says:

> On November 20, 1822, E. L. Hamlin sent to Professor Silliman, at Yale College, a box of minerals from the locality, with letters and catalogue as follows: * * *. In the catalogue Mr. Hamlin mentions lilac-colored mica as found in small globular concretions.

A large specimen of the pegmatite rock in front of Mr. Bowker's barn, at Mount Mica, shows a number of these spheres of lepidolite,

[a] Vom Rath, G., Die Insel Elba: Zeitschr. d. d. geol. Ges., vol. 22, 1870, p. 649.
[b] Hamlin, A. C., The History of Mount Mica, pp. 16–17.

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several centimeters in diameter. At Auburn, Me., several specimens of globular lepidolite were found in the summer of 1904 by Mr. Wade, working on Pulcifer's ledge on Mount Apatite. Some of these were fairly large, one such specimen (by no means the largest) collected by the writer being 6 cm. in diameter and 2½ cm. thick. Here, at Mount Apatite, this globular form of lepidolite is abundant and forms one of its characteristic phases. It often has a whitish border (a few millimeters thick) of some undetermined mineral (probably a mica) surrounding it.

## 20. LIBETHENITE.

Some minute crystals of libethenite, about a millimeter in diameter, from Yerington, Lyon County, Nev., proved to be well adapted for measurement. As the symmetry of the mineral has been regarded as orthorhombic by some writers and monoclinic by others, it was hoped that the measurement of these crystals might contribute something to the question. The results have been very satisfactory and show that the crystals measured are orthorhombic and not monoclinic.

The crystals were collected by Mr. D. Smith, to whom the writer is under obligations for the material investigated. Qualitative chemical tests showed the presence of copper, phosphoric acid, and water.

Some time after these measurements were made an article by Melczer[a] appeared on the symmetry and form of libethenite, in which he came to the same conclusion as the writer in regard to the symmetry of the mineral, his conclusion being based on a large number of measurements of Cornwall crystals. There can therefore hardly be any more question as to the orthorhombic character of libethenite.

The crystals measured are minute, less than a millimeter in diameter, but well formed, and the faces usually give very good and sharp signals. As the unit prism is present on all crystals, they were easily adjusted in true polar position and could be quickly and accurately measured with the two-circle goniometer.

Under the microscope the crystals always extinguish parallel to the crystallographic axes. No phenomena, such as twinning structure or twinning lamellæ, could be observed, either under the microscope or on the goniometer.

Seven of the most perfect crystals were removed from the matrix and measured. The forms observed are: $b=\{010\}$, $m=\{110\}$, $^*h=\{540\}$, $\delta=\{310\}$, $^*l=\{410\}$, $e=\{011\}$, $d=\{101\}$, $\{s=111\}$.

[a] Melczer, G., Ueber Libethenite: Zeit. f. Kryst., vol. 39, 1904, p. 288.

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The angles measured and calculated[a] for the eight forms given are:

| No. | Letter. | Symbol. Miller. | Measured. $\phi$. | | Measured. $\rho$. | | Calculated. $\phi$. | | Calculated. $\rho$. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | ° | ′ | ° | ′ | ° | ′ | ° | ′ |
| 1 | *b* | 010 | 0 | 01 | 90 | 00 | 0 | 00 | 90 | 00 |
| 2 | *m* | 110 | 46 | 11 | 90 | 00 | 46 | 10 | 90 | 00 |
| 3 | *h* | 540 | 52 | 26 | 90 | 00 | 52 | 28 | 90 | 00 |
| 4 | *δ* | 310 | 71 | 46 | 90 | 00 | 72 | 15 | 90 | 00 |
| 5 | *l* | 410 | 77 | 02 | 90 | 00 | 76 | 30 | 90 | 00 |
| 6 | *e* | 011 | 0 | 00 | 35 | 03 | 0 | 00 | 35 | 04 |
| 7 | *d* | 101 | 89 | 56 | 36 | 11 | 90 | 00 | 36 | 10 |
| 8 | *s* | 111 | 46 | 11 | 45 | 22 | 46 | 10 | 45 | 23 |

Besides these the prism $t=\{210\}$ seems to be present on one crystal, though the reflection was very poor and the measured angle varies several degrees from the calculated value.

Measured ($\phi$), 61° 55′, calculated ($\phi$), 64° 21′.

The new prism $h=\{540\}$ occurs but once, giving a fair reflection.

The new prism $l=\{410\}$ occurs five times, once as a broad face and the other times as a narrow face.

Goldschmidt does not give the form $d=\{101\}$ in his Winkeltabellen, but Melczer gives the form as present on his crystals, and it also occurs as long, narrow faces on the crystals measured by the writer.

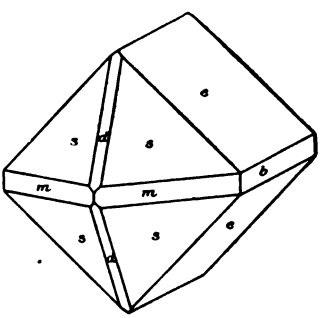



FIG. 12.—Libethenite.

In habit the crystals differ somewhat from that shown in Dana's system, inasmuch as on the Nevada crystals the pyramid *s* is large, equal in size to the brachydome, thus making the prism faces subordinate in size. The general appearance of these crystals is shown in fig. 12.

[a] Calculated angles taken from Winkeltabellen.

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The combinations observed are shown in the following table:

| Crystal No. | *b* | *m* | *h* | *δ* | *l* | *e* | *d* | *s* |
|---|---|---|---|---|---|---|---|---|
| 1 | — | *m* | — | — | — | *e* | — | *s* |
| 2 | *b* | *m* | — | — | — | *e* | — | *s* |
| 3 | *b* | *m* | — | *δ* | *l* | *e* | *d* | *s* |
| 4 | *b* | *m* | — | — | — | *e* | *d* | *s* |
| 5 | *b* | *m* | — | — | *l* | *e* | *d* | *s* |
| 6 | *b* | *m* | — | — | — | *e* | — | *s* |
| 7 | *b* | *m* | *h* | — | *l* | *e* | — | *s* |

From all the good measurements, 27 values for $p_o$ and 24 values for $q_o$ were calculated, the average values being

$$p_o = .7308$$
$$q_o = .7014,$$

which agree very closely with those given by Goldschmidt, namely:

$$p_o = .7311$$
$$q_o = .7019.$$

The values obtained for $p_o$ and $q_o$ are as follows:

| $p_o$. | | $q_o$. | |
|---|---|---|---|
| Values. | Measurements. | Values. | Measurements. |
| .7295 | 2 | .6993 | 2 |
| .7297 | 2 | .7002 | 3 |
| .7301 | 1 | .7004 | 2 |
| .7302 | 1 | .7005 | 1 |
| .7303 | 3 | .7010 | 1 |
| .7304 | 3 | .7011 | 3 |
| .7305 | 1 | .7014 | 1 |
| .7308 | 1 | .7016 | 1 |
| .7309 | 1 | .7018 | 2 |
| .7312 | 3 | .7021 | 1 |
| .7314 | 2 | .7022 | 2 |
| .7316 | 3 | .7026 | 2 |
| .7319 | 2 | .7028 | 2 |
| .7321 | 2 | .7034 | 1 |
| Av., .7308 | 27 | Av., .7014 | 24 |

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The difference in the $\phi$ and $\rho$ angles, for the forms, calculated from the two values, differ not more than a minute.

The average value obtained by Melczer is

$$p_o = .7309$$
$$q_o = .7027.$$

Taking the average of all three sets of values, we have

| $p_o$ | $q_o$ |
|---|---|
| .7308 | .7014 |
| .7311 | .7019 |
| .7309 | .7027 |
| Av., .7309 | Av., .7020 |

The axial ratio for libethenite then becomes

$$a : b : c = .9605 : 1 : .7020.$$

## 21. CRYSTALLOGRAPHY OF LEPIDOLITE.

A group of lepidolite crystals was collected by the writer in the summer of 1904 at a gem mine about 4 miles east of Ramona, on the stage road from Ramona to Julian, San Diego County, Cal. The mine was opened and worked for its gems, such as topaz, tourmaline, garnet, etc. With these are associated quartz, orthoclase in good crystals at times several feet long, muscovite, and, rarely, lepidolite. The minerals in question all occur in the loose dirt, filling "pockets" in a pegmatite dike.

The specimen of lepidolite under consideration consists of a group of intergrown crystals which often reach large size. The group itself is about 5 cm. thick and the individual crystals measure about 1 cm. across the base, though crystals with a diameter of 2 cm. are not rare. The crystals are also proportionally thick, the average being from 2 to 4 mm., though a few are somewhat thicker. They are transparent and of a very pale pink color, and, in the direction normal to the vertical axis and parallel to the base, of a slightly deeper tint. They fuse easily to a white enamel, coloring the flame an intense crimson. The side faces are usually plane, not rounded nor striated, and of a brilliant polish, giving excellent signals. It is, however, extremely difficult to secure a complete crystal from the group owing to the perfect basal cleavage, which will cause a crystal to split into a number of layers. This will also at times cause part of a crystal to become slightly displaced. In consequence of this difficulty most of the crystals measured are only parts of the original crystals, and two such pieces

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measured as separate crystals may, in reality, be parts of one and the same crystal.

As may be expected, the crystals of lepidolite are similar to those of muscovite. They also show, however, some marked differences. The interfacial angles are nearly the same and the crystals are naturally referred to the same axes as muscovite. There are three marked differences between these crystals and those of muscovite: (1) The rarity of twins, only one being found in twenty-one crystals; (2) the absence of the characteristic face of muscovite, M = {221}; and (3) the presence of the *a* face {100}, occurring on 10 out of 21 crystals. The crystals are not so striated as the green North Carolina muscovites, for instance, and in many cases the faces yielded perfect signals.

The common forms are $c = \{001\}$, $b = \{010\}$, $a = \{100\}$, $e = \{023\}$, $o = \{112\}$, $\mu = \{\bar{1}11\}$, and $x = \{\bar{1}31\}$. Besides these the following have been determined: $N = \{261\}$, $z = \{132\}$, $l = \{130\}$, and possibly several others, as $\{\bar{9}23\}$, $\{\bar{9}21\}$, $\{\bar{1}12\}$; also a number of forms which occur for the most part as broad faces, giving good reflections, but having anomalous indices, and which need further study.

The most frequent combination is *c b o u x*, after which comes *c b o u x e a*. Whenever the angle (001):(010) could be accurately measured it was found to be exactly 90° 00′ in every case, and the distribution of the faces also indicates monoclinic symmetry.

It was noticed that the angle between the same forms varied slightly on different crystals. The faces were smooth and highly polished, and the angles could easily be measured with an error not greater than 1′. It is suggested that this variation is real, and is due to the fact that lepidolite is an isomorphous mixture of two end products, and as the ratio of these two products varies, the crystallographic and physical properties of the mineral also vary. Further study on the possible correlation of the various properties of the mineral is under way.

This lepidolite belongs to the "second class" of Tschermak or the "brachydiagonal class" of Scharizer—i. e., the axial plane is parallel to the clinopinacoid and not normal to it. The trace of the axial plane was always parallel to one arm of the percussion figure.

The above is only a brief preliminary statement. The detailed crystallography of the mineral will soon be published in a paper on the mineralogy of this entire field of lithium minerals in southern California.

The writer's thanks are due Mr. Dan McIntosh, jr., of Ramona, the owner of the mine.

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# METHODS AND COSTS

OF

# GRAVEL AND PLACER MINING IN ALASKA

BY

CHESTER WELLS PURINGTON



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# LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
*Washington, D. C., February 15, 1905.*

SIR: I transmit herewith a report by Mr. C. W. Purington on Methods and Costs of Gravel and Placer Mining in Alaska, and recommend its publication as a bulletin.

Placer mining in Alaska is affected by conditions which are not combined in any other field familiar to American miners. Hence new methods of operating must be substituted for those which are employed in other regions if the greatest success is to be obtained. In too many cases this fact has not been sufficiently recognized and many enterprises have therefore failed when they should have succeeded. These failures have tended to deter capital from entering a field which still presents many opportunities for profitable investment. Some of the factors which increase the cost of production of placer gold in Alaska, such as high rates for transportation, are changing for the better; others, such as the inadequate water supply and low-stream gradients which prevail in many localities, are permanent and must be met by properly applied methods of exploitation. It is these facts which led to the investigation so successfully carried out by Mr. Purington, the results of which are here presented.

It is believed that this report will stimulate the mining industry by making available, in compact form, the accumulated results of the experience of mining men in this field and by directing attention to those mining methods developed in older districts which appear to be adapted to the conditions prevailing in Alaska. While many of the figures presented, showing cost of labor, transportation, and fuel, are subject to fluctuation, with a general tendency to decrease, yet, as a comparative study of mining methods, this report will form a valuable permanent contribution to mining literature.

Very respectfully,

ALFRED H. BROOKS,
*Geologist in Charge Division of Alaskan Mineral Resources.*

Hon. CHARLES D. WALCOTT,
*Director United States Geological Survey.*



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ROCK-CUT ON MIOCENE DITCH LINE, SEWARD PENINSULA.

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# METHODS AND COSTS OF GRAVEL AND PLACER MINING IN ALASKA.

By C. W. Purington.

## INTRODUCTION.

Owing to the fact that numerous requests have been received by the Geological Survey during the last three years for information regarding the cost of operating gold-bearing alluvial deposits in Alaska and the best means of working the claims in the various districts, the preparation of a report embodying such information, in so far as is possible from data at present obtainable, was decided on.

I was requested, in the spring of 1904, by Mr. Alfred H. Brooks, geologist in charge of the division of Alaskan mineral recources, to proceed to some of the most important placer fields of Alaska during the open season of 1904 and to collect data for an economic report. I was asked also to visit the neighboring British fields of Atlin and Klondike for the purpose of comparison. Mr. Sidney Paige was assigned as my assistant for the field and office duties, and has rendered most efficient aid during the entire progress of the work.

In the north the Juneau, Atlin, Klondike, Birch Creek, Fairbanks, and Seward Peninsula districts were successively visited, and on the return a short stay was made at the gold-dredging field of Oroville, Cal. (See Pl. II, p. 14, general route map.) Data concerning the districts not visited—the Porcupine, Chistochina, Cook Inlet, Forty-mile, and Rampart, and remote parts of Seward Peninsula—have been collected from reliable sources, especially from members of the Geological Survey who have made investigations in those portions of Alaska.

## ITINERARY.

A start was made from Seattle May 26. Five days, from May 30 to June 3, were spent in the vicinity of Juneau, Alaska, where the placers of Silver Bow basin and the power plant of the Alaska-Treadwell mines were inspected. Six days, June 11 to 16, inclusive, were spent in the Atlin district of British Columbia, where ten plants were visited on Pine, Willow, Boulder, Spruce, and McKee creeks and Gold Run. Twenty-two days, June 25 to July 16, inclusive, were spent in the Klondike district of the Yukon Territory, where 32 operations were



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visited on Gold Run, Sulphur, Upper Dominion, Bonanza, Eldorado, Hunker, Last Chance, Bear, and Gold Bottom creeks. Three days, July 17 to 19, inclusive, were spent in the vicinity of Eagle, Alaska, two operations on American Creek being visited. At Circle the regular route of transportation via Yukon River was departed from. On July 22 the party started west with a pack train and reached Deadwood Creek, in the Birch Creek district, on July 24. This day and the next were spent on Deadwood Creek, where 6 operations were inspected. On July 26, 5 operations on Mammoth and Mastodon creeks were visited. On July 27, 4 operations on Eagle Creek were visited.

The route was then pursued westward over the ridge trail to Fairbanks Creek. From August 1 to 5, inclusive, nearly all the operations in the recently opened Fairbanks district were visited, including 35 operations on Fairbanks, Chatham, Cleary, Twin, and Pedro creeks. On Fairbanks Creek a junction was made with Mr. L. M. Prindle's party, and it is due to the fact that the two parties worked together in the Fairbanks district that all the operations were visited in the few days available. During the few succeeding days as much information as possible was collected in the town of Fairbanks concerning the new gold finds of the Tanana, and my party then proceeded via the Tanana, Yukon, and St. Michael to Nome, arriving there August 20. From August 21 to September 4, inclusive, 21 operations were inspected on Anvil, Glacier, and Dexter creeks and Grass Gulch, and on Newton, Peluk, and Dry creeks.

On September 5 the party proceeded to Ophir Creek via Cheenik and Council, and from September 5 to 17, inclusive, inspected 29 operations on Ophir, Crooked, Warm, Gold Bottom, Penelope, and Big Hurrah creeks and Solomon River.

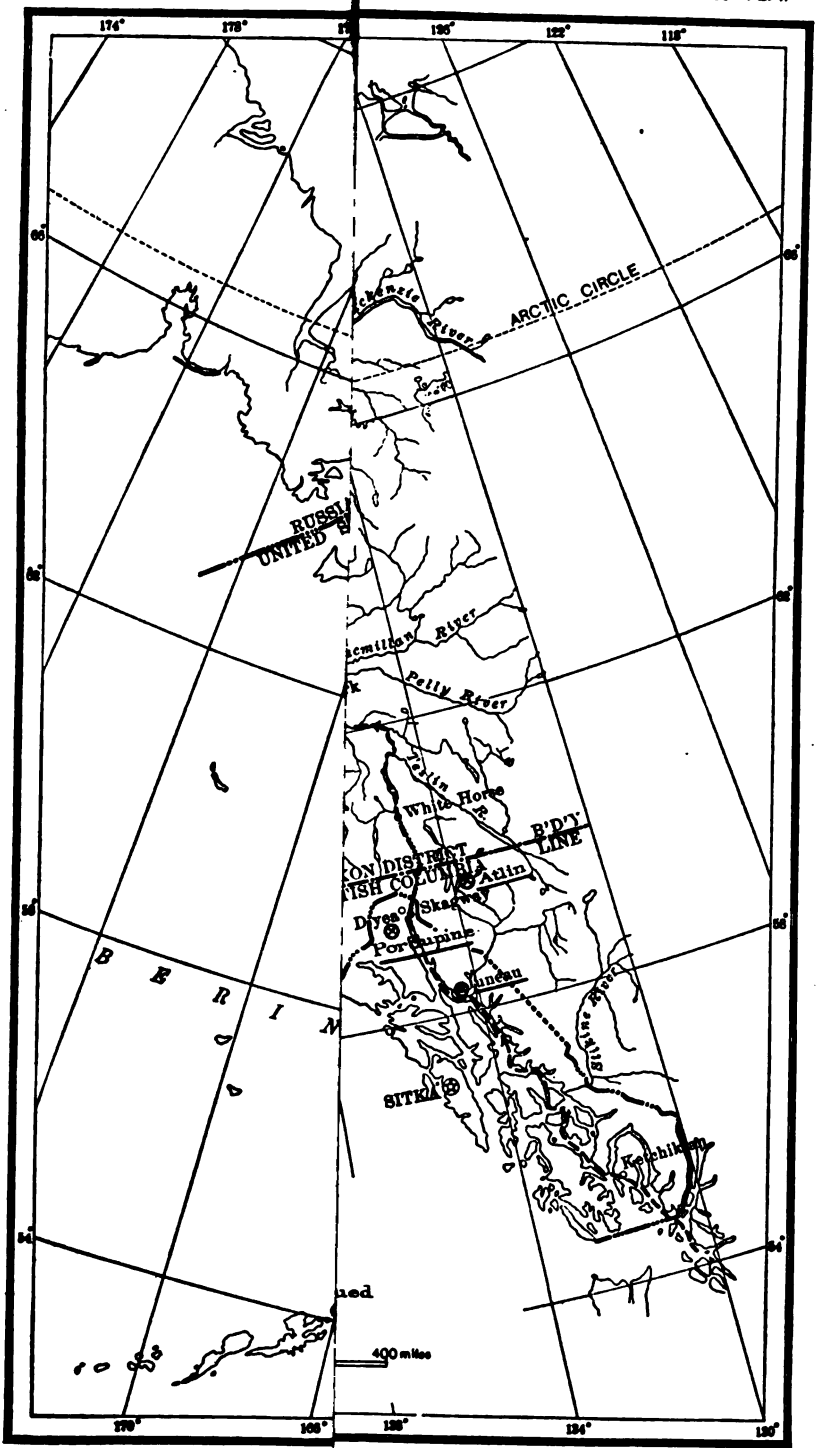
After returning to Nome a week was consumed in completing at the offices of the mining companies the data already partially obtained on the creeks and in gathering all possible information concerning operations in portions of Seward Peninsula not visited. The party arrived in Seattle October 2, and after a few days spent at Oroville, Cal., returned to Washington.

## FIELD METHODS.

Every operation in a district was not visited, but enough representative claims were examined to give a fair estimate of the cost, utility, and adaptability of each method of mining.

For assistance in obtaining the data necessary a blank, a copy of which is given on pages 17–20, was sent to all the placer miners of Alaska whose addresses were known. This blank was accompanied by a circular letter, and in many cases by a personal letter, explaining the purpose of the investigation. The fact that replies have been received from all parts of the Territory, in many cases from the most remote

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camps, shows that the mine operators take an interest in contributing to the preparation of the work in hand.

At the operations visited by myself or by Mr. Paige more detailed information was collected regarding costs, the handling of water, the setting up of the plant, and the mechanical appliances. Forms 1, 2, 3, 4, or 5 (pp. 17–25) were used, according to the character of the operations. Photographs were taken of all the operations visited. Over 400 excellent photographs have been obtained by Mr. Paige, some of which are reproduced in this report.

In each district a study has been made of the water resources, the most important factor in placer and hydraulic mining, and of the cost of building and maintaining ditches, flumes, and storage reservoirs for the purpose of using water under pressure. The important development of ditch building in Seward Peninsula has been especially considered.

The quantity and quality of timber in the mining districts has been considered with reference to its use for fuel, for building flumes and sluice boxes, and for timbering drift mines. It is an unwelcome fact that the important placer districts of the Northwest do not contain a great amount of timber, and the mining communities of the interior must use with discretion the scant supply of native timber at their command.

The questions of wages and cost of living have been considered from the standpoint of both the laborer and his employer. Temporary conditions govern wages in Alaska to a notable degree, and the table of wages applying in 1904 must be understood to have only present value. While the rate of pay for miners appears attractively high, the cost of living and of transportation to and from the country must be considered, as well as the shortness of the active season and the low rate of winter wages. Alaska presents a small field for those whose aim is limited to the earning of a day wage. On the other hand, men who are willing to work for wages during the summer, and actively and intelligently prospect during the winter with the money so earned, have always the chance of finding and locating a pay streak for themselves.

The main object has been the determination of the cost and most expeditious means of getting out the auriferous material—gravel, sand, or bed rock; of the cost of obtaining its valuable contents; of the best methods of hydraulic mining; of the cost of removing overburden under each set of conditions, and of handling the tailings; of the capacity and cost of installing mechanical methods; of the cost, capacity, and adaptability of the methods employed to thaw frozen gravel; and of the most feasible method of mining in little-developed districts.

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Care has been taken to avoid the publication of figures which were accompanied by the request that they remain confidential. It may, in general, be said that the detailed data furnished have been used mainly for the purpose of compilation, and have not been herein specifically transcribed.

In addition to matters relating directly to the operation of placer mines, attention has been given to means and cost of freight and passenger transportation. Whoever contemplates engaging in mining in the northwest portion of America, especially in the interior Alaska country, can not devote too much attention to the study of the cost of transportation of supplies. For the benefit of those who must depend on local supply points in the north for their needs, a table is given showing present costs, at each principal point, of the articles most necessary to the miner.

As regards transportation facilities, care has been taken to collect and embody in this report all available data and statistics relating to the construction of wagon roads in the Northwest. The neighboring fields of British Columbia and the Yukon Territory, in Canada, have afforded excellent opportunity to obtain costs and methods of road construction applicable to the Alaska interior. Recommendations regarding the most practical and serviceable routes for road construction in Alaska have been made in a previous report by Mr. Alfred H. Brooks.[a] The need of these roads can not be urged too strongly, and the expenditure of $1,000,000, as suggested by Mr. Brooks, would be many times repaid by the resulting development and increased gold production. Already over 300 miles of wagon road have been built by the Canadian government in the Yukon Territory and the Atlin district of British Columbia, while over 600 miles of sled roads have been made in the Yukon Territory. The fact that in the summer wagons and vehicles of all descriptions, and even bicycles, may be seen daily about Dawson, the Klondike creeks, and Atlin, in British Columbia, while the winter roads in Canadian territory afford continuous easy routes for horse sleds down the Yukon to Dawson, is evidence of the success of the Canadian road-building enterprise. On the other hand, there are in Alaska less than 50 miles of well-built wagon roads, and these have been constructed by private enterprise.

No attempt has been made to give a detailed account of the topographic and geologic conditions in the districts visited, except where such conditions have a direct bearing on the method to be employed in working the ground. The Geological Survey has already published many exceedingly valuable reports and maps, most of which are distributed free of charge. A list of the Survey publications on Alaska is given at the end of this bulletin. Any prospector who is unprovided with the reports concerning the region in which he is working lacks an important part of his equipment.

[a] Placer mining in Alaska: Bull. U. S. Geol. Survey No. 225, 1903, p. 57.

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It should be distinctly understood that the purpose of the expedition on which this report is based was not the sampling of gold-gravel deposits. Sampling is the business of the mining engineer acting in a private capacity, and is neither practicable nor permissible for officers of the Federal Government.

Information concerning the tenor of the gravels worked was frequently given by operators whose claims were visited, and such statements have been considered in the estimates of the average tenor in gold of the gravels.

On the following pages are reprinted the circular letter and the forms which were sent to miners in Alaska:

*Circular letter sent to placer miners.*

Your kind cooperation is earnestly requested in the preparation of the report on the placer mining methods of Alaska, which has been undertaken by this Office under the supervision of Mr. Alfred H. Brooks, geologist in charge of division of Alaskan mineral resources.

Mr. Chester W. Purington has been detailed to investigate some of the principal placer districts of the Northwest during the coming summer, and will personally obtain as much information as possible. It being impracticable, however, to visit each operator, you are requested to assist in the preparation of this report by furnishing such data concerning your placer and the methods employed in operating it as are asked for on the accompanying blank form. The information furnished will materially aid the investigation and will insure the inclusion of all the districts in the final report, which it is expected will be distributed in 1905.

Methods of operating are improved and rendered more effective by a community of interest, and while data furnished by you and made use of in the report may assist some other operator, you also may derive benefit from it through the suggestions of others.

The results already attained in placer mining in Alaska and neighboring territory will be made use of for the purpose of outlining the most advisable methods to be followed in each of the principal placer districts. Especial attention will be given to gold dredging, hydraulic placer mining, the employment of elevators for obtaining artificial grade, and the determination of the best methods for the thawing of frozen gravel. A special feature of the report will be a comparison of costs of operation by various methods in all parts of the placer fields. It is evident that for carrying out the plan full data are necessary concerning the character of the ground, the local conditions, and the methods at present in use.

As the value of these reports depends largely upon the promptness of their publication, an early reply is earnestly requested. Please answer the questions on the schedule as far as possible. If you can not give the exact figures in all cases, make the replies as approximately correct as possible.

A copy of the report will be sent to each operator furnishing a statement. An addressed envelope is inclosed, which requires no stamp.

*Form No. 1, sent to gold-placer miners of Alaska.*

It is hoped that even in cases where the operator does not care to give full data concerning his property and operations he will furnish at least a part of the information requested. Very few of the facts obtained will be embodied directly in the report, but from the sum of them will be drawn conclusions and suggestions which it is hoped will be of value to the gold-mining community as a whole.



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1. What is the name and post-office address of firm, corporation, or individual making this report?
2. What is the name of mine?
3. What is the location of mine, and in what district? (NOTE.—Give name by which district is commonly known, such as "Birch Creek," "Ophir Creek," etc.)
4. By whom is the property owned?
   Address:
5. By whom is the mine managed?
   Address:
6. (*a*) How long has the mine been operated, and what was date of opening?
   (*b*) How many ounces of gold has it produced?
   (*c*) What was the gold worth per ounce?
7. What is the character of the deposit? (Creek, bench, river bar, seabeach, or gravel plain.)
8. (*a*) How many acres does it contain?
   (*b*) What are its approximate dimensions?
9. How many men are employed, and how much are they paid?
10. How many shifts are worked, and how many men on each shift?
11. Between what dates is gravel extracted?
12. Between what dates is it washed?
13. (*a*) Is there timber on the property?
   (*b*) If so, how much, and of what kinds and average size?
   (*c*) What does sawed lumber cost per thousand?
   (*d*) Where is sawed lumber obtained?
14. (*a*) If gravel is in a stream bed, what is the grade of the stream per mile, in feet?
   (*b*) How many miner's inches or cubic feet of water are used in mining operations, and for how many months in the year?
15. How much, in dollars or cents, must the gravel contain per cubic yard to pay?
16. How far below the surface does the pay gravel lie?
17. Will you please describe a section of the overburden, giving the succession and thickness of turf, soil, sand, round or angular gravel, clay, etc.?
18. (*a*) Does pay lie directly upon bed rock? (*b*) If not, upon what does it rest, and what is beneath?
19. How wide and thick is the pay?
20. Does it follow any definite channel or channels?
21. Is there more than one pay streak?
22. Is the pay gravel sandy or clayey?
23. (*a*) Is the gravel rounded or angular?
   (*b*) What is the usual diameter of the stones?
   (*c*) What per cent are over 6 inches in diameter?
   (*d*) What per cent are over 18 inches in diameter?
24. (*a*) Is ground frozen?
   (*b*) If so, to what depth?
25. (*a*) Is bed rock hard or soft?
   (*b*) What kind of rock?
   (*c*) If slate, or thinly bedded rock, what is its angle or dip?
26. (*a*) Is bed rock excavated in mining?
   (*b*) To what depth?
27. (*a*) Do you get coarse or fine, flaky or shot gold?
   (*b*) Are nuggets found?
   (*c*) Of what size?

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28. (*a*) Is gold smooth or rough?
    (*b*) Rusty or bright?
    (*c*) Flat or chunky?
29. (*a*) Does nature of gold vary from grass roots to pay or in different parts of the pay streak?
    (*b*) If so, in what way? Please describe.
30. (*a*) What amount of black sand is caught per cubic yard of gravel washed?
    (*b*) What amount of other materials?
31. (*a*) Are other valuable minerals caught besides gold?
    (*b*) If so, what are they and in what amount?
32. Under which of the following heads do your operations come, and will you briefly describe the important features? (Operations: tundra, beach, creek, or bench mining.)
33. How many cubic yards of gravel are washed per day during the season?
34. How many cubic yards of overburden are stripped during the season?

PROSPECTING GROUND.

1. (*a*) Has ground been prospected by pits or by drill holes?
   (*b*) If by pits, what was the size and depth?
2. (*a*) How many were dug?
   (*b*) What did they cost?
3. (*a*) Did they need timbering?
   (*b*) If so, how closely and how heavily?
4. If ground was prospected by drilling, what size, depth, and number of holes were used?
5. (*a*) What was the cost per foot?
   (*b*) What was the cost of equipment?
6. What difficulties were encountered?
7. How did the results from mining compare with the probable results as indicated by prospecting?

HYDRAULIC OPERATIONS AND EQUIPMENT.

1. How much water is used, and how is it distributed in the operations?
2. What is the length, capacity, and grade of ditches, and head and tail flumes?
3. What is the length and size of pipe lines, and of what is pipe made?
4. Will you kindly describe giants, as to size, make, capacity, effectiveness, etc.?
5. How are bowlders handled?
6. What and how much material is consumed, such as lumber, quicksilver, powder, etc.?
7. What is the effectiveness of a giant upon frozen gravel?
8. How much gravel is moved in 24 hours, and what does it cost?
9. Are elevators used, and if so, what has been your experience with them?
10. How much water do they use?
11. Of whose make are they, and will you kindly describe them?
12. How large stones will they handle?

DREDGING.

[NOTE.—If blueprints or photographs are furnished, they will be returned if desired.]

1. Will you kindly give a general description of dredge: Maker, type, size, estimated capacity, cost, and some details of construction; especially of new features that have proved advantageous.
2. How are bowlders handled?

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3. How deep will buckets or dipper dig?
4. What is capacity of buckets?
5. What are arrangements for moving dredge and holding it in place?
6. How is gravel sized?
7. Are plates or quicksilver used?
8. What is the life of wearing parts?
9. What kind of power and engines are used?
10. What fuel is used, and what is its cost?
11. What type of pumps are used, and what is their capacity?
12. How many cubic yards of gravel have been handled in a given time from past record?
13. What special difficulties are encountered?
14. What is cost of dredging under local conditions?
15. Is frozen ground encountered, and if so, how does dredger work in it?

In case of special operations not covered by the above summary, will you kindly give brief descriptions, especially of apparatus which has proved successful in handling placer gravel under northern conditions?

The following space is left blank in order that any special description of the property may be given.

You are requested to fill out this schedule as soon as possible and return in the inclosed envelope which requires no stamps.

Forms 2, 3, 4, 5, 6, contained the first thirty-four questions in form 1, and the questions in form 1 regarding prospecting ground. In addition the following data were asked for, a separate form being used according as the operations came under the heads of hydraulic mining, dredging, open cutting, or drift mining.

*Form 2.—Hydraulic mining.*

Size of head-gate.
Dimensions, grade, length, capacity, and cost of head ditch.
Cost of maintaining.
Length of flume, if any.
Dimensions, grade, and size of lumber in bottom, sides, and battening; size and length of posts and sills in head flume; number of collars to box.
Amount of trestling and cost of same. Size of sills, posts, and stringers.
Is flume or ditch covered to prevent freezing? Describe method.
Number of relief gates in ditch line.
Are inverted siphons used? If so describe.
Amount of water available.
Size pressure box and size lumber used.
Head of water in feet.
Length of pipe line from pressure box.
If more than one pressure box or pipe line, describe.
Size, gage, cost, and nature of pipe employed.
Where obtained.
Kind of joints.
Kind and number of air valves.
Method of setting and unsetting pipe.
Size of pipe at giant or giants.
Is water diverted for other purposes beside giant?
If so, how much, and for what purposes?
Number and angles of elbows in main pipe line.

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Size, make, and cost of giant or giants used.
Size nozzle used, with or without deflector.
How often is giant moved?
What height of bank is operated on?
What modifications adopted in system of piping owing to frozen gravel?
Does giant clean bed rock?
If not, how is bed rock cleaned?
How much gravel is moved per shift?
If bankhead or by wash water used, how much?
How are bowlders handled, derricking or shooting?
Cost of handling bowlders.
Size, capacity, and cost of derrick and plant; cost to operate.
At what distance is head box of tail sluice from giant?
Dimensions, grade, and length of boxes in tail sluice.
Number of boxes.
Size of lumber in bottom, side, and lining boards.
Method of making sluice box, size of posts and sills.
Cost and time to make and put in place one box.
Life of lining boards.
Largest stones put through sluice.
Average cost of shooting bed rock to keep sluice on grade.
Kind of riffles employed in the sluice—distribution.
Cost and life of same—preference of riffles.
Amount of quicksilver used.
Amount of quicksilver consumed.
Are undercurrents used? Description, number, distribution, area of each, grade, results.
Per cent of gold saved in different parts of sluice.
Per cent of gold saved in undercurrents.
Per cent of gold lost.
Is gravel forked in the sluice?
Is dump moved after leaving end sluice box?
If so, by what power and to what distance?
Are tailings impounded? If so, for what reason?
Method and cost of impounding.
Cost of breaking down, moving, and washing gravel per cubic yard.
Improvements contemplated or suggested.
If hydraulic elevator is used—make, size, weight, and cost of elevator.
Depth of sump.
Effective lift of elevator.
Pressure necessary to obtain lift.
Size of throat, upcast pipe, and nozzle.
Weight, thickness, material, life, and cost of throat.
Method of joining upcast pipe.
Shape, material, and life of hood.
Largest stones handled.
Amount of water handled by elevator.
Amount of gravel handled by elevator.
Amount of water fed to nozzle.
Are auxiliary water lifts used?
Is any method beside piping used for feeding gravel to elevator? What method.
Describe sluice boxes before elevator, if any—number of boxes, grade, dimensions, riffles.
Describe tail sluice—length, grade, dimensions, riffles.

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Per cent of gold caught before and after elevator.
Frequency, time, and cost of moving elevator.
Difficulties encountered in its use.

*Form 3.—Dredging.*

Make and cost of dredge.
Estimated and actual capacity of dredge in cubic yards per twenty-four hours.
Is dredge in a river or in self-made pond?
Depth to which buckets dig, and height of bank above water level.
Where was hull constructed and of what material?
Feet of lumber in hull and cost of hull.
Dimensions and draft of hull, loaded.
Weight of machinery.
Power used, nature, amount, cost per day.
Height, size, method of bracing, and inclination of gauntrees.
Size, weight, position, and description of spuds, if used.
Size, number, position, and use of winch drums.
Position of lever house.
Size, number, and length of cables.
Does dredge dig on spud or head line?
Length, width, weight, material, of digging ladder.
Material and weight of tumblers.
Number, capacity, arrangement, weight, shape, and cost of buckets.
Material, life, and cost of bucket lips, pins, and bushings.
Are teeth used on any buckets?
How far in front of bow will buckets dig?
What size of stones are handled?
Do buckets clean bed rock?
Describe save-all, if used.
Is nozzle used for cleaning buckets?
Is trommel or shaking screen used? Preference.
Dimensions and life of trommel; size holes.
Is side chute used for large stones? Describe grizzly.
Is sluice box with auxiliary float used? If so, describe.
Is stacking ladder used? Length, how driven, steel-link belt, or rubber belt, width.
Height and distance from stern stacked.
Life, efficiency, and cost of stacker belt.
Treatment of fines, area, grade, and description of tables; kind of riffles most successful, amount of quicksilver used.
Is sand pump used? How often?
Clean up, how often? State method used and time consumed.
Size, make, and cost of pump used for supplying sluice water; height of lift.
Distribution of power; how much to each operation.
Size and capacity of boilers and engines or dynamos used; describe connections pulleys, and clutches.
Special difficulties owing to northern conditions.
Most frequent breakages.
What kind of ground does dredge work best in?
What kind of ground does dredge have most difficulty in?
If in pond, is water pumped in? How much? From what source?
Cost per cubic yard of digging and washing gravel.

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*Form 4.—Open cut (not worked by hydraulicking).*

Depth of overburden stripped.
Method of stripping; by ground sluicing, hydraulicking, scraping, or booming.
Cost per cubic yard of stripping; amount stripped in a given time.
Source of water.
Amount of water in miner's inches.
Length of ditch or flume and dimensions.
If water is pumped for sluicing, kind of pump used and cost of pumping per cubic yard of gravel handled.
Dimensions and grade of sluice boxes and number used.
Is mud box used? Dimensions.
Disposal of large stones.
Size of lumber used; one or more strings of boxes.
System of joining and setting up boxes.
Kind of riffles, cost and life.
Dimensions of pit worked with one set-up, frequency of new set-ups, and time consumed in changing.
How is seepage water handled, by pump or drain?
Dimensions, length, grade, capacity, cost, and method of constructing drain; difficulties with drain.
Is China pump used? Capacity; cost of pumping.
Is power pump used? Capacity; cost of pumping.
Describe system of dams, if used, method of construction and cost.
How are tailings handled? If scraped by horses, cost of scraping.
Per cent of gold saved in boxes, if known.
The following special queries apply to open-cut work:
If men shovel into boxes—
- To what height do men throw?
- Are platforms used?
- Depth of ground shoveled in.
- Amount of ground handled per shift per man in cubic yards.

If horse scrapers scrape into boxes—
- How many cubic yards per day will one team scrape into boxes?
- Cost per day of team and driver.
- Per cent of gold saved.

If steam scraping is employed, in handling pay or tailings—
- Describe plant and cost, cost of operation, capacity, and difficulties encountered.
- Amount and kind of fuel used.
- Number of men required to scraper.
- Distance to which material is conveyed, and height elevated.

If derricking is employed—
- Describe capacity of plant, give cost, system of operating, amount and distribution of power and labor.

If inclined track and car system is used—
- Number and capacity of cars handled per shift; number and length of tracks in use.
- Length of tram to bottom of incline.
- Number of men to a car.
- Length of incline and vertical height of dumping platform above bed rock.
- Amount of power to elevate; system of elevating, automatic devices used.

If steam shovel is used—
- Size, make, capacity, and cost of shovel.
- Power used, amount, and how generated.
- Capacity of dipper.

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If steam shovel is used—
- Length of boom.
- Weight of machine.
- On track or skids.
- Height of bank on which it will operate.
- Does it clean bed rock, or do men clean bed rock after it?
- Efficiency in digging the material at hand.
- Does it dump into cars or sluice boxes?
- Is conveying system equal in capacity to shovel?
- Difficulties encountered.
- Cost per cubic yard of digging.
- Elevation to which gravel is hoisted in cars, power necessary for hoisting.
- Describe track system for returning empty cars.

If more than one of the above systems is in use for working open cuts on the same claim, give comparative efficiency and cost.

*Form 5—Drift mining.*

Dimensions of shaft.
Cost and rate of sinking per foot.
Is shaft timbered?
Method of timbering shaft.
Depth of shaft to bed rock.
Unfrozen gravel—
- Method of drifting.
- What width of face is carried?
- Are pillars left, what dimensions?
- Height of posts, length of caps.
- Are false sets used?
- Method of filling or caving worked-out ground.
- Are timbers recovered?

Frozen gravel—
- Rate and cost of sinking shaft by steam point.
- Diameter of steam pipe entering shaft.
- Length, diameter, and cost of points.
- Pressure of steam, size of cross-head.
- How far apart are points placed in face?
- Is hot water used in starting points? Preference.
- Horsepower per point.
- How long are points left in face?
- Cubic yards of gravel thawed by each point in given time.
- System of mining and hoisting.
- If gravel thawed by hot-water hydraulicking, describe method.
- Size, capacity, and cost of pump.
- Position of pump.
- Temperature of and method of heating water.
- Amount of water used.
- Size nozzle used.
- Cubic yards of gravel thawed per shift.

Boiler—kind, make, cost.
Kind, amount, cost of fuel burned per day.
Distribution of power, to thawing, to hoisting and conveying.
If gravel thawed by wood fires, describe method; give cost and capacity.
Describe system of tramming, wheeling, or skidding to shaft.
Describe system of hoisting.
Is self-dumping carrier used? Kind, efficiency.

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To what distance and height above the collar of shaft does it transport the gravel?
Capacity of the plant.
Cost per cubic yard of mining, hoisting, and washing.
What area of ground is worked from one shaft?
If winter dumps are taken out and washed in spring—
Size of dump.
Method of sluicing.
Cost of sluicing.
Is dump rethawed?
Method and cost of rethawing.
Method of sampling dump, if any.

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## GENERAL STATEMENT OF CONDITIONS.

Placer mining is that form of mining in which the surficial detritus is washed for gold or other valuable minerals. When water under pressure is employed to break down the gravel, the term *hydraulic mining* is generally employed. There are deposits of detrital material containing gold which lie too deep to be profitably extracted by surface mining, and which must be worked by drifting beneath the overlying barren material. To the operations necessary to extract such auriferous material the term *drift mining* is applied.

As nearly all mining in alluvial deposits comes under the head of gravel mining, that term has been adopted in the main for operations described in the report of which the following chapter is a summary.

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Occasionally, however, the precious mineral sought lies in a matrix of fine sand, or even entirely in the crevices of the bed rock on which the alluvial deposit rests. Obviously the term gravel mining does not cover the cases in which detrital gold is extracted from such matrices, and the general term placer mining[a] has been, therefore, added in the title of this report for want of a name which shall include all operations considered.[b] When in the subsequent matter the terms gravel deposit, gravel washing, and gravel mining are employed they must be understood, for the sake of brevity, to include the consideration of all classes of deposits in which gold of detrital origin is found.

The term "*elluvial*" has been applied to placer deposits formed by the rotting of rock in place to greater or less depth.[c] Such deposits do not occur in the portions of Alaska visited, and may be excluded from consideration.

In regard to the valuable contents of the deposits, it should be stated that in all the cases here considered gold is the mineral sought. Platinum or any minerals of the platinum group have not been found in paying quantity in any part of Alaska. Alluvial tin has been found and mined in the western portion of Seward Peninsula. The deposits were not, however, visited by the present expedition.[d]

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[a] *Placer*, according to a Spanish definition, is a place near the bank of a river where gold dust is found. Lindley on Mines, sec. 419, makes the following comments:

"Dr. R. W. Raymond (Glossary of mining and metallurgical terms, Trans. A. I. M. E., vol. 9, p. 164) defines the word placer as a deposit of valuable mineral found in particles in *alluvium* or diluvium, or beds of streams. He adds to the definition the statement that, by the United States Statutes, all deposits not classed as veins or rock in place are considered *placers*. As was said by the Supreme Court of the United States (Reynolds *v.* Iron S. M. Co., 116 U. S., 687-695; 6 Sup. Ct. Rep., 601), in distinguishing the two classes of deposits: 'Placer mines, though said by the statutes to include all other deposits of mineral matter, are those in which this mineral is generally found in the softer material which cover the earth's surface, and not among the rocks beneath.'"

It is evident that the term placer mining as used in the present report covers a much more limited field than would be the case were the term placer used in its broad legal sense.

[b] The term *alluvial mining*, used in Australia, is not generally employed in the United States.

[c] Eng. and Min. Jour., vol. 77, May 5, 1904, p. 722.

[d] See the report of A. J. Collier (Bull. U. S. Geol. Survey No. 229, 1904) for an exhaustive account of the York tin deposits.

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## CLASSIFICATION OF ALLUVIAL GOLD DEPOSITS IN ALASKA.

The alluvial gold deposits of Alaska may be classified as follows:

*Classification of alluvial deposits in Alaska.*

| | |
|---|---|
| Creek placers | Placers in, adjacent to, and at the level of small streams. |
| Hillside placers | Placers on slopes, intermediate between creek and bench claims. |
| Bench placers | Placers in ancient stream deposits from 50 to 300 feet above present streams. |
| River-bar placers | Placers on gravel flats in or adjacent to the beds of large streams. |
| Gravel-plain (tundra) placers. | Placers in the coastal plain of Seward Peninsula. |
| Sea-beach placers | Placers adjacent to the seashore to which the waves have access. |
| Lake-bed placers | Placers accumulated in the beds of present or ancient lakes; generally formed by landslides or glacial damming. |

The methods of working the alluvial gold deposits are shown in the following table:

*Methods of working alluvial gold deposits of Alaska.*

| Class of placers. | Method of working. |
|---|---|
| Creek placers | Hydraulicking. |
| | Hydraulicking with hydraulic elevator. |
| | Dredging. |
| | Open cutting, separate[a] stripping, and shoveling in.[b] |
| | Open cutting, separate stripping, and horse scraping. |
| | Open cutting, separate stripping, and steam scraping. |
| | Open cutting, separate stripping, wheeling, and cable tram. |
| | Open cutting, separate stripping, and steam shovel. |
| | Open cutting, separate stripping, track and incline system. |
| | Open cutting, separate stripping, track system, with hydraulic elevator. |
| | Open cutting, separate stripping, track system, with derricking. |
| | Open cutting, separate stripping, skidding, with derricking. |
| | Shaft, drifting, and timbering. |
| | Shaft, thawing, and drifting. |
| Hillside placers[c] | By the same methods as creek claims. |

[a] Charged to independent account. The stripping generally consists of frozen "muck," a mixture of silt and ice, which is ground-sluiced off.
[b] Includes rocker work.
[c] Detritus varying from 3 to 60 feet in thickness.

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*Methods of working alluvial gold deposits of Alaska*—Continued.

| Class of placers. | Method of working. |
|---|---|
| Bench placers [a] | Hydraulicking. |
| | Open cutting, separate stripping, and shoveling in. |
| | Open cutting, separate stripping, and horse scraping. |
| | Shaft or adit, drifting, and timbering. |
| | Shaft or adit, thawing, drifting, little timbering. |
| River-bar placers [b] | Hydraulicking with hydraulic elevators. |
| | Dredging. |
| | Open cutting, steam shovel. |
| Gravel-plain (tundra) placers. [c] | Hydraulicking with hydraulic elevating. |
| | Open cutting, separate stripping, and shoveling in. |
| | Shaft, thawing, and drifting. |
| Sea-beach placers [d] | Digging shallow pits and shoveling in. [e] |
| | Dredging. |
| | Special devices. |
| Lake-bed placers | Hydraulicking. |

[a] Detritus varying from 5 to 150 feet in thickness; in parts of Seward Peninsula to 230 feet.
[b] Detritus from 3 to 60 feet in thickness.
[c] Detritus from 15 to 150 feet in thickness.
[d] Detritus from 1 to 6 feet in thickness.
[e] The greater part of the gold from the beach sands has been obtained by rockers.

The above classes are based on operations actually seen during the season of 1904. Suggestions concerning the application of other methods to certain forms of deposits are given in the body of the main report.

In the districts (Pl. II, p. 14) visited the deposits under exploitation as above classified were as follows:

*Classes of deposits worked in districts visited.*

| Province. | District. | Class of placer worked. |
|---|---|---|
| South Coast | Juneau | Creek and lake-bed placers. |
| Interior | Atlin | Creek and bench deposits. |
| | Klondike | Creek, hillside, and bench placers. |
| | Eagle | Creek and bench placers. |
| | Birch Creek | Creek, hillside, and river-bar placers. |
| | Fairbanks | Creek placers. |

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*Classes of deposits worked in districts visited*—Continued.

| Province. | District. | Class of placer worked. |
|---|---|---|
| Seward Peninsula... | Nome ..... | Creek, hillside, bench, gravel plain, and seabeach placers. |
| | Council ..... | Creek, hillside, and river bar placers. |
| | Solomon..... | Creek and river bar placers. |

In the districts not visited the classes of deposits are as follows:

*Classes of deposits worked in districts not visited.*

| Province. | District. | Class of deposit worked. |
|---|---|---|
| South Coast ..... | Porcupine ..... | Creek and bench placers. |
| | Nizina ..... | Do. |
| | Chisna ..... | Creek placers. |
| | Sunrise..... | Do. |
| Interior ..... | Fortymile ..... | Creek and bench placers. |
| | Rampart ..... | Do. |
| Seward Peninsula... | Topkok ..... | Creek, gravel plain, and seabeach placers. |
| | Port Clarence..... | Creek and bench placers. |
| | Fairhaven ..... | Do. |
| | Kougarok ..... | Do. |

## METHODS OF MINING, AND CONDITIONS.

The mining of placer gold in Alaska is carried on for the most part during June, July, August, and September. The gold-bearing gravel mined during the remainder of the year by winter drifting does not exceed 15 per cent of the total annual amount extracted. The gold can not be washed from this gravel until the cessation of winter conditions liberates the water in spring for sluicing purposes. The sluicing of the "winter dumps" takes place during the latter part of May.

Many of the methods of mining have been developed within the last ten years to suit the unusual conditions existing in the northern gold fields. Gravel miners from other parts of the world found that in Alaska much of their previous experience proved of no special benefit. On the other hand, men without previous experience in mining, but possessing ingenuity, have occasionally adopted devices which have proved efficient and adequate to meet the northern conditions. Methods which had been condemned or tried with ill success in other countries have given good results in Alaska, while the attempts to apply hydraulic or mechanical methods of established reputation elsewhere have frequently resulted in ignominious failure.

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Mining operations have been made difficult by the short available season, the lack of grade to the streams, poor water supply, poverty of timber resources, high cost of labor and transportation, concentration of gold on and in the bed rock, and comparatively large thickness of barren overburden, the frozen, or worse still, half-frozen condition of the gravel, lack of wagon roads, and inadequate mining and police regulations. In spite of these obstacles the wide and fairly uniform distribution of alluvial gold over large areas of Alaska, hitherto unexploited, the uniformly healthy and even enjoyable climate of the country, and the near proximity of the phenomenally rich gold fields of the British Yukon Territory, offer a certain justification for the present energetic prospecting and mining for gold over so extensive an area.

The main impressions derived from an inspection of the placer gold fields of the north are as follows: (1) Operations requiring the installation of expensive plants are frequently undertaken before adequate sampling of the ground has been done; (2) the methods of mining and conveying the auriferous material, while often leaving much to be desired from the standpoint of economy, are, in the main, developing along favorable lines; (3) the gold-washing and gold-saving appliances in use are, in numerous cases, inexcusably crude and inefficient.

The winning of gold from alluvial material is a business difficult both to learn and to conduct successfully. The careful miner, like the careful manufacturer, will give as much attention to one part of his business as to another, irrespective of the scale on which it is conducted. The extensive but not remarkably rich gold-bearing area of Alaska offers a field for men who propose to conduct their operations with energy, intelligence, and economy. To others it can afford only ultimate poverty and despair.

The South Coast province is characterized by heavy grades, abundant water supply, and good timber. Gold-bearing gravels are, however, distributed in small quantity and, however good the conditions for the installation of hydraulic plants, the province remains an unimportant producer of alluvial gold.

The Interior province promises to continue for many years a fairly important producer. Geographically considered, the phenomenal Canadian deposits of the Klondike come under this province. No gravels approaching the Klondike deposits in richness have been found on the American side, but a large area yet remains to be prospected.

Owing to the topographic conditions, low grades to creeks, and insufficient water supply at an available elevation, hydraulicking on any but the smallest scale is impossible. Many of the creek deposits are shallow, and, besides the primitive method of shoveling into sluice boxes so largely in practice, there is a considerable field for the installation of horse-scraping methods and the installation of simple mechan-

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ical plants. Solidly frozen creek deposits exceeding 15 feet in depth can be most economically worked by drifting methods, as heretofore. Experience gained in the Klondike has been invaluable to the miners now developing the new Fairbanks field. There is room, however, for considerable improvement and reduction of expense in the methods employed.

The natural conditions prevailing in the Alaska interior gold field imply great age and erosion subsequent to any deposition beneath sea level. Topographic conditions exercise a remarkable control over the methods which can profitably be employed in gravel mining, and the prospective miner neglects a vital part of his preparation if he does not study the topographic features of a given district in detail before entering upon his operations. In California and Australia the geologic and topographic conditions favor the placer miner. In other countries, notably Siberia, Alaska, and the Yukon Territory, they are inimical to his success. In Alaska, as a rule, alluvial gold is almost entirely lacking where timber and water are plentiful, grades are steep, and the ground is unfrozen. Where gold is distributed in paying quantity, water supply is inadequate, timber is poor or altogether lacking, the miner must provide grade for his boxes and dump for his tailings by artificial means, and must meet the formidable obstacle of solidly frozen alluvium. Bench deposits, where gravel can be moved on natural grade, occur in both the Fortymile and Rampart districts of interior Alaska, and have been made to produce a small amount of gold by the hydraulic method. Although it is not impossible that extensive and valuable bench deposits may yet be found, no deposit comparing either in extent or in richness with the famous "White Channel" of the Klondike has been discovered.

In that portion of the Alaska interior lying between Circle, on the Yukon, and Fairbanks, on the Tanana, the mountains rise to heights of from 1,500 to 2,000 feet above the level of the streams, have rounded tops, and slope to the intervening valleys at angles which do not exceed 20 degrees, and often are not greater than 10 degrees. The streams and valleys are on a gently descending plain, the grade of which does not exceed 3 per cent, except in the upper one-half mile, and frequently is not over 1 per cent. The mountains are referred to by the inhabitants as "domes," and the word fairly well describes them. They present what corresponds most nearly to the upper segment of a great ellipsoid except in places where the erosion has not been sufficient to accomplish the obliteration of a still more ancient topography. This ancient surface, remnants of which are visible on the tops of the highest mountains, was evidently a base-leveled plain, which was approximately 2,500 feet above the present drainage plain. Although the base-leveling is apparent to the eye, it is not evinced by the presence of rounded gravel on its surface. The lack of gravel is

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accounted for by the fact that the second denudation has progressed for a great period, and the comparatively small amount or vertical section of gravel which existed subsequent to the elevation has been worn away.

In the Klondike recent streams have cut the old Pleistocene channels and have reconcentrated the gold.[a] The gold is about equally distributed in the old and in the new gravels. From the miner's standpoint, therefore, in the Klondike region there are two great classes of mining to be considered, namely, creek mining and bench mining. Outside of these two classes there is no mining in the Klondike of productive importance.

In the Birch Creek district, especially on Deadwood Creek, there is a very small amount of gravel in low benches which may be termed hillside deposits. The bulk of the mining, perhaps 90 per cent of it, is creek mining in its various forms. The terms bench deposit, hillside deposit, and the like are very loosely applied by the miners of the Northwest, and names are given to classes of mining to which they do not in any sense apply. This looseness of nomenclature is apparent in the Fairbanks district, where the term bench mining is applied on Cleary Creek to operations in progress on the left bank of the stream at a place one-fourth mile above the junction of Cleary and Chatham creeks. But whereas the depth to bed rock in the main creek at this point is 18 feet, the depth on the so-called bench, 700 feet to the left, is 53 feet, and the level of the bed rock at which the gravel is found is practically the same. In the one case, namely, in the creek working, the overburden is 6 feet of muck, while in the "bench" to the left the overburden is over 45 feet of muck. The gently sloping side of the valley at this point is unbroken in outline.

Observations along the various producing creeks and from the hilltops have failed to distinguish any traces of bench topography in the Fairbanks district. Such placer mining as is carried on there comes under the head of creek mining. Geological evidence, however, suggests that bench deposits occur in the region lying between the Fairbanks and Rampart districts.

The methods applicable to bench mining at Dawson can not be used in the Fairbanks district, and all thought of applying them must be eliminated. The country being in every sense of more gentle topography, there is no room for the disposal of tailings from bench operations conducted by hydraulicking.

On Pedro and Twin creeks there are about 2 miles of ground less than 15 feet in depth which can be worked by open cutting, either by shoveling into sluice boxes or by derricking. On a portion of this ground it is possible to handle the water by bed-rock drain. Open-cut mining has also been successful on Chatham Creek near its junc-

[a] See McConnell, R. G., Preliminary report on the Klondike gold fields: Geol. Survey Canada, 1900.

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tion with Cleary. In all other portions of the district, so far as developed, drift mining according to the Klondike system of thawing either by steam or hot-water hydraulicking, hoisting, and conveying by means of the self-dumping bucket on cable tram will probably be found most economical. I would suggest the method of underground hot-water hydraulicking to the miners of Cleary Creek, while on Fairbanks Creek steam thawing appears to be advisable. The efficiency of the hot-water method as used in the Klondike is from 5 to 6 cubic yards per horsepower generated in the boiler as against 3 cubic yards with steam. The method can, however, be applied only under certain favorable conditions.

In Seward Peninsula the greater rainfall, larger catchment areas at the heads of the long rivers, and the comparative cheapness with which ditches can be constructed has led to the investment of much capital in long water conduits. For example, a ditch system of 54 miles, built at an expenditure of $300,000 and costing $15,000 annually to maintain, supplies 2,000 miner's inches of water at 360 feet head for four months in the year. Approximately 200 miles of ditches have been built in various parts of the peninsula. Excavations of earthwork for ditch building in the peninsula average $1 per cubic yard.

Hydraulicking without the use of hydraulic lifts is economically impossible, except in extremely rare cases. Bench gravels in the front of Anvil Mountain, facing the sea, can be hydraulicked if water at a sufficient head can be obtained at an expense which is not prohibitive. The remarkable ancient gravel channel which cuts the southern portion of the peninsula from east to west, extending from Fish River along Casadepaga and Kuzitrin rivers to Port Clarence, lies at so low a level that the present streams have not cut through it to bed rock. Except where subordinate pay streaks exist in it above the present stream, therefore, the physiographic conditions will forbid its gravels being hydraulicked, while any other form of open cutting is manifestly impossible. It has been little explored, and portions of it may be found rich enough to drift.

Horse scraping, steam or power scraping, derricking, and the application of the mechanical shovel, accompanied in most cases by ground sluicing of the frozen muck, should receive consideration from the creek operators in Seward Peninsula, where the deposits are less than 15 feet in depth. The low price of winter labor ($2.50 a day and board) should permit of an increasing amount of winter drifting work throughout the peninsula.

It will doubtless eventually be found that the power of water under pressure can be more successfully applied to the working of the average Seward Peninsula placer by generating electric power and applying it to various mechanical devices. While it can not be denied



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that some of the hydraulic elevator installations are handling the gravel at a profit, the contrivance is a makeshift, and its use forms no part of bona fide hydraulic mining.

## COST OF MINING.

The average value of fuels in Alaska as shown by present operations is as follows:

*Cost of fuels available for use in Alaska.*

| | |
|---|---|
| Bituminous coal, price at Nome | $17 per ton (2,000 pounds) |
| Crude oil at Nome | $3 per barrel |
| Spruce wood, average price in the interior | $12 per cord |

Experience in the Nome district indicates that California crude oil is the most economical fuel available in the southern part of Seward Peninsula. In the interior of Alaska the price of imported crude oil renders its use prohibitive for mining operations.

The recently exhibited tests of the adaptability and efficiency of gas-producing engines should receive attention from operators who contemplate the installation of mechanical plants in any part of Alaska. There is no question that bituminous coal and lignite can be utilized for gas producers, giving proportionately better results than anthracite. An engineer operating a large pumping plant in the Klondike is of the opinion that even the poor spruce wood available for fuel in interior Alaska can be utilized in the gas-producer engine. The prejudices which exist againt the explosion type of engine in the United States are fast disappearing. They have been due to faulty construction of the engines and lack of knowledge of their principle among those who attempt to operate them. The present valid objections to installing gas and gas-producer engines are that these engines are undergoing a process of evolution, and the standard has not been attained. According to Mr. M. R. Campbell, the Government coal-testing plant at St. Louis has demonstrated that a gain of from 30 to 50 per cent of efficiency is attainable in the gas-producing as compared with the steam-producing engine.

The comparatively low cost of California crude oil at Nome renders it a valuable fuel for the mining operations in that vicinity. The satisfactory results from one type of gas engine at St. Louis showed that crude oils of widely varying composition can be used with a higher efficiency in generating gas for explosive engines than in generating steam.

The purchase of water for hydraulic or sluice purposes is not general in Alaska. In Seward Peninsula water under natural head or pumped water is sold to miners to a limited extent. The average price is $1 per miner's inch, twenty-four hours' service, for water under head and 50 cents for sluice water. The inch used corresponds to 1.2 cubic feet per minute. This measure of the miner's inch is not accepted in this report. The miner's inch, according to its best

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definition, which is followed in this report, corresponds for all practical purposes to a flow of 1.5 cubic feet per minute. It is to be hoped that if the Federal Government ever succeeds in establishing an adequate code of mining law for its possessions a definition of the miner's inch will be included.

The data in the table on page 38 were compiled from statistics collected during an inspection made in the summer of 1904 of the placer fields in Alaska, Yukon Territory, and northern British Columbia. Of the statements furnished by operators, only those which are considered reliable have been used. The work attempted had no relation to the sampling or valuing of mining properties, and time did not permit, except in a few cases, the measuring of the ground.

Owing to the varying conditions governing the cost of mining in the North, the Territory has been divided into three provinces. The South Coast province includes the Juneau, Porcupine, and Sunrise districts of Alaska. The Interior province includes the Atlin district of British Columbia, the Klondike district of Yukon Territory, and the Fortymile, Eagle, Birch Creek, Fairbanks, and Rampart districts of Alaska. The Seward Peninsula province includes the Nome, Council and Solomon districts of Alaska.

The Nizina district of the South Coast province and the Port Clarence, Fairhaven, and Kougarok districts of Seward Peninsula, none of which were visited, are separately considered.

In preparing the sheet the working costs of 118 different operations were first tabulated with reference to the method employed and to situation. A second table was then prepared, in which the working cost was augmented by an amount per cubic yard based on allowance for depreciation of plant. In general, six years was taken as the average life of an individual property, and, except in the case of winter drifting operations, one hundred and twenty days as the working season. It was then assumed that five annual payments are made to a depreciation fund. The fund is equivalent to the cost of plant and maintenance during the life of the property plus six years' simple interest on the investment at 5 per cent. Each annual payment was divided by the season's output in cubic yards, and the amount thus obtained was added to the daily working expenses, to get the total output cost per yard, as far as possible. Prices paid for mining property are not considered, as they represent an unknown factor.

In cases where expensive plants have been installed the amortization was calculated separately for each case.

In cases of shoveling-in and small mechanical plants, the installation and maintenance cost was taken at an average amount for a group of operations in each district. Where the operation implies an additional stripping of overburden, which is always separately charged, the cost was distributed and added to the gravel extraction cost.

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From the second table, where the costs were reduced to one figure for each district, a third (table 1, p. 38) was prepared, giving as nearly as possible the average cost for each of the seventeen separate methods considered in one or more of the three provinces. Where the operations from which the averages are derived exceed two in number, the fact is so indicated in the table.

The attempt has been made to reject figures which were evidently not representative. The final figure arrived at is not, however, always satisfactory. For example, under No. 5 (the method of working open cut by shoveling into wheelbarrows, wheeling to bucket, hoisting and conveying to sluice by self-dumping carrier on cable) $2.14 is representative for the Klondike, where seepage water is generally pumped from the pit, and many operators pump the water for sluicing. On the other hand, at a plant in the Birch Creek district of Alaska, mining only 22 cubic yards per day and handling the water by a drain, the cost of operation was $1.50 per cubic yard. In No. 13 (drifting solidly frozen ground, steam or hot-water thawing, hoisting and conveying with the use of the self-dumping bucket) the cost in the Klondike is $1.95, while the higher figure given is arrived at by combining the expensive American camps of Fortymile and Fairbanks, where the cost is $4.63 and $3.56, respectively.

The high cost of hydraulicking with use of hydraulic lift in Seward Peninsula is caused by the difficulty of moving the gravel to the bed-rock sluice[a] and the expense of the ditches and installations. Hydraulicking by means of water under natural head without the use of the hydraulic lift, or some other means of elevating the material, was not seen by me in Seward Peninsula. It is understood that a hydraulic plant is in successful operation at Bluff, 50 miles to the east of Nome, but there are no data at hand concerning it.

In the interior only bench gravels are hydraulicked. Steeper grades for sluices can be obtained, and the gravel is more easily moved. The high duty of the miner's inch in the Klondike is a large factor in bringing down the cost of No. 1 and No. 16.

It should be distinctly understood, if hydraulicking costs in the interior appear attractively low, that the water supply is exceedingly variable, and that no reliable estimate can be made beforehand of the output of a given season's operations. Furthermore, while much of the bench gravel was originally rich, the pay streaks have been largely drifted out, and the gold is not disseminated through the upper portion of the gravel to the extent that it is in the California gravel banks. With regard to the pumping of water for hydraulicking purposes, the practice can not be too strongly condemned. He is a bold man who attempts it, and a singularly fortunate one who makes a financial success of it.

[a] This is caused not only by the exceedingly gentle grades of the streams, but also by the shingly character of the material handled.

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Mr. Stephen Birch, operating in the Nizina district of Alaska, has courteously furnished for this report a summary of the costs of working placer ground on Dan Creek. These figures are given separately (p. 39) after the table, as they imply a total charge of invested capital in addition to working costs against one season's operations. They are worth the attention of prospective placer miners.

The cost of shoveling into sluice boxes in the remote parts of Seward Peninsula is at present from $3 to $5 per cubic yard. Some drifting operations have been carried on in the Kougarok and Fairhaven districts, on which figures are not at hand.

Dredging estimates furnished by reliable interior operators place the cost at 80 cents per cubic yard where gravel must be thawed by points ahead of the dredge. In Seward Peninsula it is estimated that if the property is sufficiently large for a ten-year life, a dredge can be operated at the cost of 30 cents per cubic yard. The field for dredges in placer mining in Alaska is extremely limited. In Seward Peninsula it is not impossible that some of the wide, shallow creek deposits will be worked successfully by means of the steam scraper. The cost of an experimental operation on Ophir Creek was reported to be under 20 cents per cubic yard.

The costs of operating by two mechanical systems in Seward Peninsula (involving the labor of men in shoveling into cars and tramming to the bottom of an incline, or into a bed-rock sluice leading to hydraulic elevator throat) are unfortunately not available for publication. The derricking system, No. 7, however, both in the interior and in Seward Peninsula, appears to be superior in point of cost to either of the above mentioned methods for working the average Alaska open cuts.

Frozen ground can not be attacked with success by the steam shovel. Even where it digs the gravel successfully, if men follow it to clean bed rock by hand, the cost of operating is sometimes doubled. The steam shovel has, however, a field in northern placer mining.

Regarding mechanical operations in general, the important principle should be emphasized that the main expense is getting the material into the receptacle which conveys it to the sluice or washing plant. Tramming even for a long distance, and to a considerable elevation, adds a very small proportionate amount to the total cost of working. The establishment of a permanent washing plant, economically situated as regards water supply and dump, should be considered by every Alaskan miner who proposes working the shallow creek deposits which characterize that country. The isolation of the washing operations, together with the adoption of the most economical system of tramming possible, will go far toward attaining the ends of adequate grade and room for tailings, which are the essential features of successful gravel mining.

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TABLE 1.—*Average capacity and cost of gold-gravel mining operations in northwestern America.*[a]

| | 1. Hydraulicking, no pumping of water. | 2. Hydraulicking with use of hydraulic elevator. | 3. Open cut; shoveling into sluice boxes, including stripping top dirt; no pumping. | 4. Open cut; horse scraping. | 5. Open cut; shoveling; wheeling to bucket; cable tram to sluice. | 6. Open cut; shoveling into cars; track and incline to sluice. | 7. Open cut; shoveling into buckets or skips; skidding or tramming, and derricking to sluice. | 8. Open cut; shoveling into sluice; tailings by hydraulic lift. | 9. Open cut; steam-shovel excavating; track and incline to sluice. | 10. Open cut; steam scraping; generally on stripping work or tailings. | 11. Dredging. | 12. Drifting partly frozen or thawed ground requiring timbering. | 13. Drifting and thawing solidly frozen ground; little or no timbering. | 14. Winter drifting and spring sluicing of dumps. | 15. Mining or stripping overburden by ground sluicing. | 16. Hydraulicking by means of pumped water. | 17. Booming with self-dumping water gate. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SOUTH COAST PROVINCE. | | | | | | | | | | | | | | | | | |
| Number of operations considered. | 6 | 6 | 6 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Capacity, cubic yards, in 24 hours. | 833 | 350 | 54 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Thickness of deposit, feet | 30.3 | 25 | 5.6 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Thickness of gravel worked, feet. | 30.3 | 25 | 3.7 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Cost[b] | $0.20 | $0.31 | $2.01 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| INTERIOR PROVINCE. | | | | | | | | | | | | | | | | | |
| Number of operations considered. | 13 | ..... | 20 | ..... | 8 | ..... | ..... | ..... | ..... | 6 | ..... | ..... | 7 | ..... | ..... | 4 | ..... |
| Capacity, cubic yards, in 24 hours. | 1,049 | ..... | 63 | 105 | 162 | 450 | 233 | 184 | 800 | 92 | 1,062 | 50 | 75 | 50 | 150 | 830 | 250 |
| Thickness of deposit, feet | 37.4 | ..... | 8.6 | 20 | 17.5 | 14 | 15 | 8 | 22 | 15 | 35 | 60 | 26.4 | 26.4 | 9 | 33 | 7.5 |
| Thickness of gravel worked, feet. | 37.4 | ..... | 3.5 | [c]10 | 4.5 | 5 | 9 | 6 | 22 | 8.7 | 35 | 4 | 4.36 | 4.36 | [d]9 | 33 | [c]6 |
| Cost[b] | $0.238 | ..... | $2.39 | $0.60 | $2.14 | $2.43 | $1.75 | $1.25 | $1.46 | $0.49 | $0.49 | $4.25 | $3.38 | $5.14 | $0.17 | $0.65 | $0.07 |
| SEWARD PENINSULA PROVINCE. | | | | | | | | | | | | | | | | | |
| Number of operations considered. | ..... | 4 | 10 | 5 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 3 | ..... |
| Capacity, cubic yards, in 24 hours. | ..... | 658 | 145 | 200 | ..... | ..... | 550 | ..... | 1,000 | ..... | 700 | 80 | 20 | 83 | 173 | 250 | ..... |
| Thickness of deposit, feet | ..... | 12 | 6.6 | 5 | ..... | ..... | 15 | ..... | 30 | ..... | 8 | 20 | 35 | 85 | 4 | 23 | ..... |
| Thickness of gravel worked, feet. | ..... | 12 | 3.3 | 5 | ..... | ..... | 11 | ..... | 27 | ..... | 8 | 7 | 4 | 4.3 | [d]4 | 23 | ..... |
| Cost[b] | ..... | $0.89 | $1.87 | $0.46 | ..... | ..... | $0.91 | ..... | $0.52 | ..... | $0.43 | $4.49 | $3.66 | $4.61 | $0.10 | $0.93 | ..... |

[a] Lost time, the prices paid for mining property, and the cost of equipment other than that relating to actual mining (e. g., railways, wagon roads, etc.) are not taken into account, and any estimates based on these figures must make due allowance for these expenses; otherwise the costs here given will be found two low.

[b] Dollars per cubic yard.

[c] "Muck" and top gravel.

[d] "Muck" or fine silt and ice; from 50 per cent to 75 per cent ice.

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Mr. Stephen Birch, in a letter, gives the cost of placer work on Dan Creek, Nizina district, Alaska, as follows:

By ground sluicing through 20-inch flume: 6,803 cubic yards, $8,781.44, or $1.143 per cubic yard.

By use of 8-inch cotton pressure-hose and nozzle through 20-inch flume: 1,600 cubic yards, $1,457, or $0.91 per cubic yard.

By use of pick and shovel only, through 10-inch sluice box: 2,320 cubic yards, $5,100, or $1.875 per cubic yard.

A 273-foot tunnel, 6 feet by 6 feet, timbered: $1,017, or $3.725 per running foot, or 407 cubic yards of gravel removed, which costs $2.50 per cubic yard.

While the cost given above may seem high, it is because of the fact that it includes the cost of the tools and material now on hand, which were necessary to remove this gravel. Now, if this work is continued on for a number of years, the depreciation of the tools, etc., could by charged proportionately. These prices may not be a criterion for future operations in that country but were our first cost of operation, and any strangers going into that section of country would be apt to run up their costs to these figures.

## PROSPECTING.

Creek claims must be prospected by shafts, open cuts, or drill holes. Shafts are generally used and are most practicable for the Alaska miner. Open cuts are not practicable, except in very shallow ground. Drilling requires expensive equipment, the machines costing from $3,500 to $4,000 delivered in Alaska. As a means of prospecting auriferous gravels drilling is very satisfactory, but it is generally employed only in deep gravel beds, where dredging is contemplated.[a] In such ground excess of water prohibits the sinking of shafts. The cost of drilling with a 6-inch core churn drill is $2.50 per foot in California, and the tests of the deep gravels of the coastal plain have shown it to be practically the same in the vicinity of Nome, on Seward Peninsula. The cost of drilling depends on the price of labor and fuel, and will probably be about $3.50 per foot in the interior of Alaska. Unless contractors are found already equipped to do the work, drilling is more expensive than sinking pits, the cost of which varies from $3 to $8 in Alaska placer fields.

In the solidly frozen ground encountered in northern placers it is not necessary to sink the casing around the pipe as in ordinary drilling. In partly frozen ground, where the casing is necessary, much difficulty has been found in pulling it up. A driller of the churn type is shown in Pl. III, *A* (p. 40), mounted on a scow for prospecting the bed of Snake River, Seward Peninsula.[b] The results obtained by drilling when compared with actual tenor of the ground are variable. In testing the bed of Solomon River the results were found to run 7

[a] See a further description of prospecting by drill holes, by Mr. J. P. Hutchins, in the chapter on dredging, later in this report.

[b] For description of drilling operations in testing placer ground see Knox, N. B., Dredging and valuing dredging ground at Oroville, California: Trans. Inst. Mining and Metallurgy, June 18, 1903. Also Smith and Stebbins, Gold dredging at Oroville: Eng. and Min. Jour., Dec. 8, 1904.

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per cent lower. In all parts of Alaska drill holes should be not less than 100 feet apart, on account of the unequal distribution of the gold. Geologic conditions at Oroville, or in other dredging fields of flood-plain character, are radically different. There the ratio of holes is 1 to an acre or 1 to 5 acres.

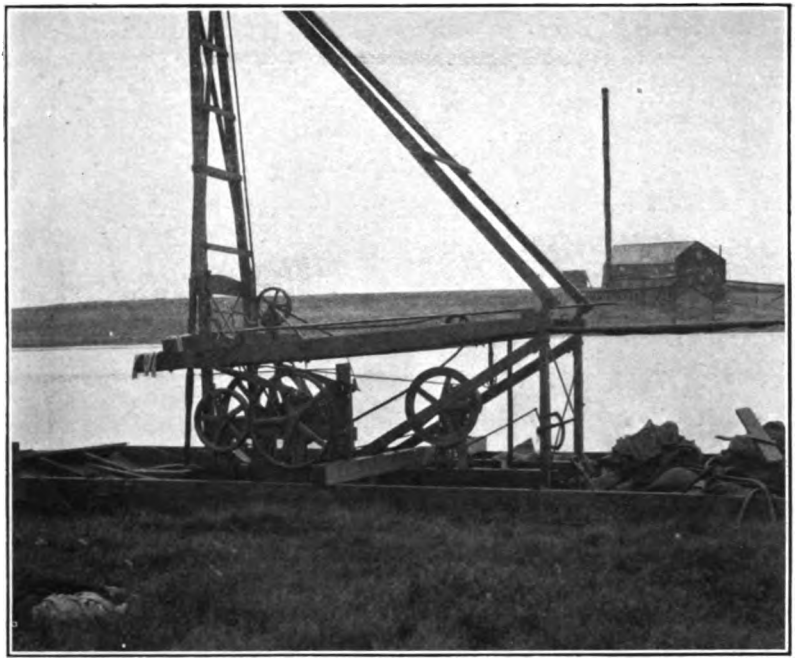
Shallow bench gravels can occasionally be prospected by diverting a high stream or water from a ditch in a direction transverse to the gold-bearing channel. The water will ground sluice a trench to bed rock, thus crosscutting the ground. Such prospecting is done in the Fortymile district, and an example of it was seen on Gold Bottom Creek, in the Council district of Seward Peninsula.

Bench gravels covered by heavy overburden are usually prospected by drifts. Drifts require timbering and are more expensive than shafts, but give a more satisfactory test of the ground. In rich pay streaks the running of prospect drifts often more than pays the cost. Owners of claims sometimes get their ground partly prospected by letting out the right to drift to two or more men, who pay a royalty on the gold they take out. In the Nizina district a 20 per cent royalty is charged on prospect work.

When ground is prospected by shafts the distance between the shafts varies, although the variation is not so great as when the prospecting is none by drill holes. The practice in Alaska varies according to the work, the resources of the owner, and the depth of the ground. Where the gold has not traveled far and in consequence the values are spotted, shafts should be sunk 30 to 50 feet apart, but such close work is never done. Twenty shafts to a 20-acre claim are common. Shallow ground, 6 to 18 feet deep, can be well and cheaply prospected in the winter months. Deep ground, as in the Fairbanks field, is expensive to prospect, and the prospect shafts do not average four to a claim. The cost of sinking shafts in the various camps is given below.

Twenty shafts, 3½ by 6 feet and 12 feet in depth, timbered in thawed ground, or untimbered in frozen ground, cost from $1,200 to $2,000. If steam thawing is employed, the outfit, consisting of a 6-horsepower boiler, three or four steam points, steam hose, and pipe connections, will cost from $300 to $500. Hot stones, hot water, and wood fires are more generally employed in prospecting ground in the remote camps. The hardest ground to prospect is that which is partly frozen. For example, in the Birch Creek and Fortymile districts shafts 15 to 25 feet in depth penetrate frozen ground and require no timbering until they are within 5 feet of bed rock, when a rush of water is frequently encountered. The entire labor of sinking the shaft through the overlying barren material may be lost, as the shaft may be flooded before pay gravel is reached.

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*A*. CHURN DRILL MOUNTED ON SCOW, SNAKE RIVER, ALASKA.



*B*. WINTER DUMPS, KLONDIKE.

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## COST OF PROSPECTING IN DIFFERENT LOCALITIES.

In the Juneau district prospect shafts must be square set, and cost on an average $6 a foot, and in heavy landslide $20 a foot. In the Porcupine district the cost of a cut 25 by 12 feet and 40 feet deep is $50 per foot, and that of an 8- by 8-foot shaft is $20 per foot. In the Sunrise and Chisna districts ground is prospected by open cuts. A cut 50 feet in length is reported to cost $2,000.

At Atlin ground is prospected mostly by drifting. On McKee Creek tunnels, timbered and lagged, cost $3.50 per foot. On Spruce Creek the cost of posts and caps, 10 inches thick and 6 feet long, is 50 cents each; lagging, 10 cents each. On Gold Run thirty 6-inch holes are said to have been drilled to a depth of 32 feet by a churn drill (cost, $3,500, laid down), at the rate of $1 a foot.

In the Klondike drifts to prospect the bench gravels cost $7 to $8 a foot, timbered, and shafts from $5 to $10 a foot. In timbering, three sets of posts, sill, cap, and lagging are put in for $6, and as one-half cord of wood is used to a set the whole cost is $7 per set. In frozen creek ground two men, working three shifts, sunk a pit 5 feet square, 28 feet deep, using about 2-horsepower steam during thirty hours.

On Fortymile Creek, thawing ten hours, two men take out on an average 4 feet a day, the shaft being 5 feet by 3½ feet in dimensions. On American Creek prospecting is very difficult, as running water is always encountered at bed rock, even in the coldest weather.

In the Fortymile district shafts averaging 3½ by 6 feet, untimbered, cost from $3 to $5 per foot. Seven shafts 4 by 8 feet and 23 feet deep cost $2,000. A shaft 7 by 3½ feet and 20 feet deep cost $5 per foot, the thawing being effected by means of wood fires and steam.

In the Birch Creek district shafts thawed down by wood fires to a depth not exceeding 20 feet cost $5 per foot. On Mastodon Creek, in this district, 11 pits 3 by 6 feet and 20 feet deep cost $650. Twenty pits 3 by 6 by 13 feet cost $7 per foot. The differences in cost here are due to the varying amount of permanent frost in the ground, prospecting always being cheapest in solidly frozen ground. On Mammoth Creek 100 pits 10 feet deep cost $5 per foot. Wood fires were used, 2 feet being sunk each day. No timbering was required, and labor was paid $10 a day.

In the Fairbanks district the prospect shafts cost from $7 to $10 per foot. Timbering is generally necessary, but very light poles are used either as lagging or cribbing. The best system is to put in 6-foot sets of 3-inch poles, and outside of these to lag with 2-inch poles vertically, filling in solidly between the poles and the muck or gravel with moss. Shafts cribbed with poles horizontally are more likely to get out of plumb. Four shafts sunk on lower Fairbanks Creek cost $5 per foot, and were 32, 44, 53, and 54 feet deep. On Cleary Creek a shaft 4 by 6½ feet and 75 feet deep (hillside claim), cribbed with 3-inch poles, cost

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$560. Wood fires were used in thawing. On Pedro Creek 19 pits 3½ by 7 by 12 feet cost $1,140, and on an adjoining claim pits 3 by 6 feet and 18 feet deep cost $6 per foot. The light timbering and moss filling used in the Fairbanks mines is to prevent the muck walls from thawing and caving.

In the Rampart district 30 pits 3 by 6 feet and 20 feet deep cost from $75 to $100 each. The ground was partly thawed, but required no timbering.

In the Nome district, on account of the entire lack of native timber, shafts are cribbed with 1 or 2 inch planking, set close together, no sets being used. On the Snowflake bench claim, on Anvil Creek, the cribbing was reenforced by 2 by 4 inch posts in the corners. Five dollars per foot is the average cost of 4 by 5 shafts, timbered, in unfrozen or partially frozen ground.

On Bonanza Creek, near Nome, pits in the shallow creek bed, 3 by 7 feet and 7 feet deep, are said to cost 50 cents per foot.[a] The ground is only lightly frozen and requires no timbering. On Ophir Creek, in the Council district, it costs on an average $5 to sink pits 7 feet deep.

In the northern part of Seward Peninsula the ground is solidly frozen. In the Kougarok district pits 35 feet in depth, with steam thawing, cost $8 per foot, and require no timbering.

In the Candle or Fairhaven district, adjacent to Kotzebue Sound, 28 pits 12 to 15 feet deep cost $4 a foot. It was necessary to thaw to bed rock. The equipment cost $500.

## RESULTS OF PROSPECTING.

Numerous reports from many parts of Alaska indicate that the amount of gold obtained per cubic yard from prospect shafts does not equal that extracted by subsequent actual mining. The reverse is very rarely true. It is difficult to assign a reason for this discrepancy other than that, owing to the frozen condition of the gravel, some of the gold escapes when small lots are washed in the winter. Frozen gravel does not easily disintegrate, even in hot water, and unless the residue from panning or rocking is saved and rewashed, losses very likely occur.

It is needless to urge the importance of prospecting ground in a thorough manner before expensive machinery is installed. The many failures through the long history of mining which have resulted from precipitate expenditure to exploit supposed valuable properties present an open page of admonition to him who cares to read.

The sampling of winter dumps as they are extracted does not appear to have received the attention which it deserves. A method used by Mr. Kelley, of Dominion Creek, in the Klondike, is as follows:

The ordinary conical dump of frozen gravel, Pl. III, *B* (p. 40),

[a] This work is probably done in the winter with labor at $2.50 a day and board.

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assumes a somewhat steeper angle than that of loose material. One measured in the Klondike had a slope of 40°. From experience it has been found that if the ground is of uniform richness, 80 per cent of the values are contained in the upper two-thirds of the dump, which has a content of approximately 8,000 cubic yards. The apex of the dumps is generally 30 to 40 feet above the base. Four times each day 5 pans are taken in sampling—one from each quadrant of the dump one-half way down from the top—and one pan from the apex. The results of the 20 pannings are put together before weighing, and 50 per cent of the result is taken for the average value of what has been taken out during the day.

Neglect to apply some form of sampling to the dumps has caused many lamentable failures in the Klondike. Winter operators of the Fairbanks district should keep themselves assured by constant sampling that the gravel they are getting out at such a cost carries values.

## WATER SUPPLY.

### CLIMATIC CONDITIONS.

Land areas in high northern latitudes are characterized by distribution of their natural resources that is unfavorable to economic use. In Alaska the great forests that characterize the south coast are replaced by stunted growths of spruce in the gold fields of the interior and by willow copses in Seward Peninsula. During a normal year the rainfall at Juneau, as may be seen from table 2 (p. 48) compiled by Dr. Cleveland Abbe, jr., is over eight times as great as at Eagle, on Yukon River. The catchment area at Juneau is only 4 square miles, and, as the grades of the hillsides are precipitous, the rainfall quickly runs off. A small amount of the water is used for power in connection with milling operations and for mining placer gold. The short, steep creeks and rivers of the south coast have small catchment basins, and even were there any use for the water for placer-mining purposes, there would be difficulty in impounding it after the melting of the snows in June and July.

Large catchment basins exist in the interior of Alaska, but the water to fill them is unfortunately lacking. At Eagle, where the annual rainfall is 11.4 inches in a normal year, the drainage area of Mission Creek and its tributaries which flow into the Yukon is nearly 200 square miles. Of the amount of water caught in a given area, however, very little is available for mining purposes. As an illustration take the case of American Creek, a tributary of Mission Creek. The only placer mining on it is done at a point about 12 miles distant from its mouth, at an elevation of 1,600 feet. As the use of water for hydraulic mining requires a head of 200 feet, and as the height of the divides which surround American Creek does not exceed 3,000 feet, it is evident that the only catchment area available is that lying between 1,800

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and 3,000 feet, and between the mine and the head of the creek, or its short tributaries. Of a total catchment area of nearly 75 square miles for American Creek, only 15 square miles are available for the operations at the point referred to. If it were possible to catch all the water, say 11.4 inches in depth, which fell on this area during a season, and use it in hydraulic mining, it would amount to 1,500 miner's inches available for one hundred and twenty days, and would move gravel at the rate of 1 cubic yard to the inch of water. As in practice it is not possible to utilize at head over one-third of that theoretically available in the catchment area, the capacity of the water power available is reduced in proportion. (See fig. 1.)

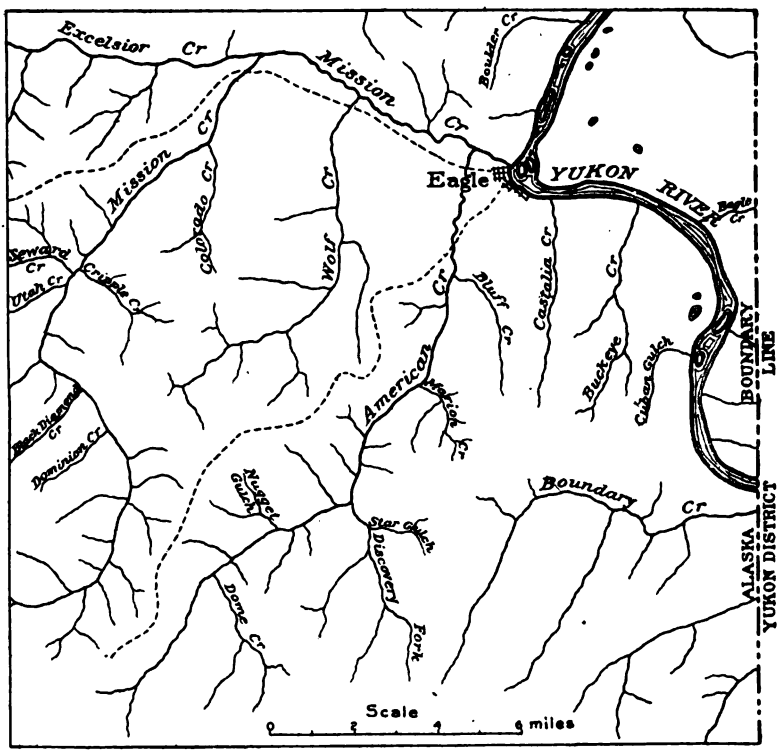



FIG. 1.—Map showing American Creek drainage, Eagle district.

In certain parts of the Fortymile region it is not impossible that water conduits from 10 to 15 miles in length can be constructed to bring water to the placer diggings. The Glacier Mountains, lying west of the upper portion of Mission Creek, rise to heights of 6,000 feet, or 3,000 feet higher than the general level of the interior country, and should afford a more promising water supply than any other area adjacent to the interior placer mining districts. The great drainage system of the South Fork of Fortymile Creek may also be available to a less extent for obtaining water under pressure. Miners should

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bear in mind, however, that even if the water is at hand and the gravel deposit extensive, the attempt to work by the hydraulic method where a grade of 6 inches to 12 feet can not be obtained will probably fail.

In the Fairbanks and Birch Creek districts the rainfall may be assumed to be no greater than that at Eagle. The catchment area that lies at an elevation sufficient to supply the placer ground with water at a proper head for hydraulic operations is insignificant. Even were the auriferous gravels in that district so situated as to be hydraulicked, water for that purpose could not be obtained. The small amount of water which runs in the creek bottoms is available at heads not exceeding 25 feet, by means of ditches, for sluicing purposes. It is of variable quantity, however, and must be husbanded with the greatest care. The promiscuous cutting of timber and stripping of moss, which are the inevitable accompaniments of the exploitation of the

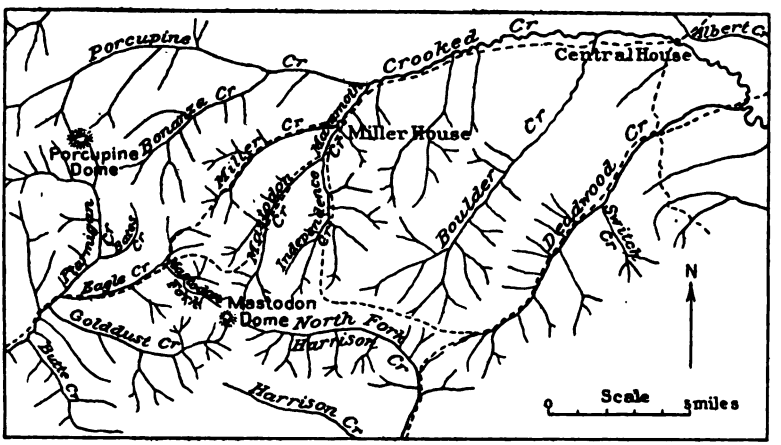



FIG. 2.—Map of part of Birch Creek district.

placers, will tend to gradually diminish the supply of water. (See figs. 2 and 3.)

Of the interior districts the Rampart and Fortymile appear to be most copiously supplied with water, and these are the only districts in the hitherto developed interior where considerable bench deposits have been found. It seems not improbable that a survey with reference to locating the larger catchment areas at sufficient elevation may result in obtaining water for hydraulicking the bench gravels.

No data are at hand with reference to the rainfall in Seward Peninsula. It may be assumed to be larger than that of the interior, and is probably fairly represented by the figure given for St. Michael, 18.1 inches, which fell during the summer of 1904. This amount, however, was much less than that of the year before, and the gold product of the peninsula was thereby materially reduced. The facilities for making use of the water for mining purposes are better on

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Seward Peninsula than in the interior. The available catchment areas on the peninsula are larger, and the construction of water conduits, owing to peculiar conditions which will be described, can be undertaken more cheaply. The Kigluaik Mountains and the Bendeleben Range, lying roughly parallel to, and at a distance of 25 miles north of, the important gold fields of the South Coast, rise to heights ranging from 2,000 to 4,000 feet, and afford, as has been proved, a fairly continuous water supply during the open season. The York Mountains,

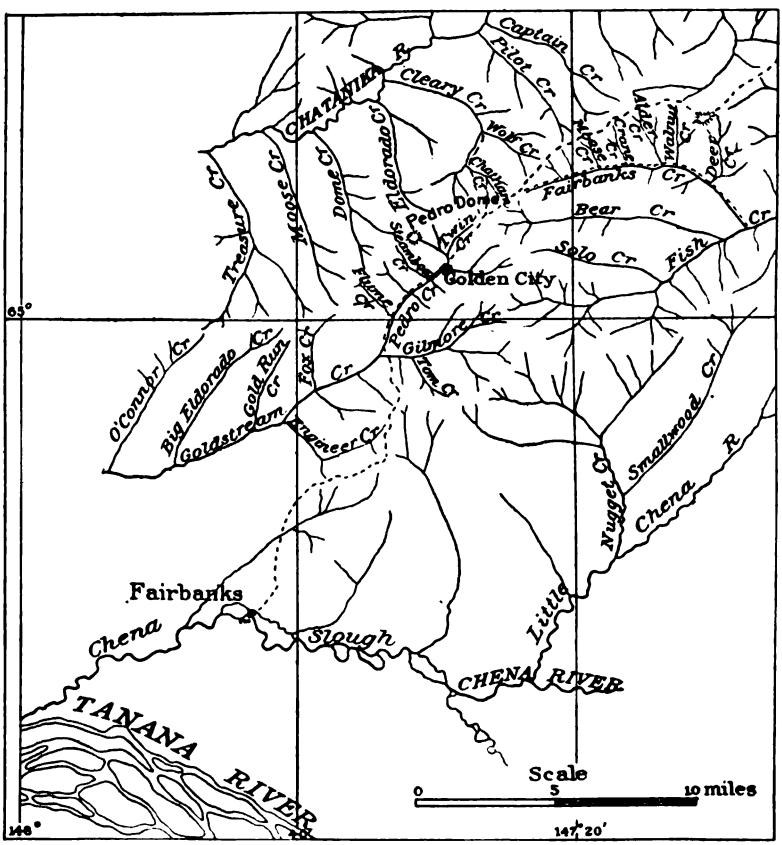



FIG. 3.—Map of part of Fairbanks district.

in the western portion of the peninsula, will doubtless furnish a similar water supply should occasion require. Already the extensive ditch systems of Nome River, Ophir Creek, and Solomon River afford an aggregate of 5,000 miner's inches of water in the drier portions of the open season. (See fig. 4.) The expenditure for this work already made will probably not fall far short of a million dollars. Projects for the construction of water conduits are in contemplation which compare favorably with, and even exceed in magnitude, those already completed.

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That the expense attendant on ditch construction in Seward Peninsula is justifiable in certain cases is not to be denied. That the most profitable method of converting the water into power has always been applied is, however, decidedly open to question. The subject will be further discussed under the head of "Hydraulic mining."

The average annual rainfall in California at various points on the west slope of the Sierras is approximately as follows:

| | Inches. |
|---|---|
| Sacramento | 19 |
| Auburn | 20 |
| Colfax | 54 |
| Cisco | 60 |
| Summit | 48 |

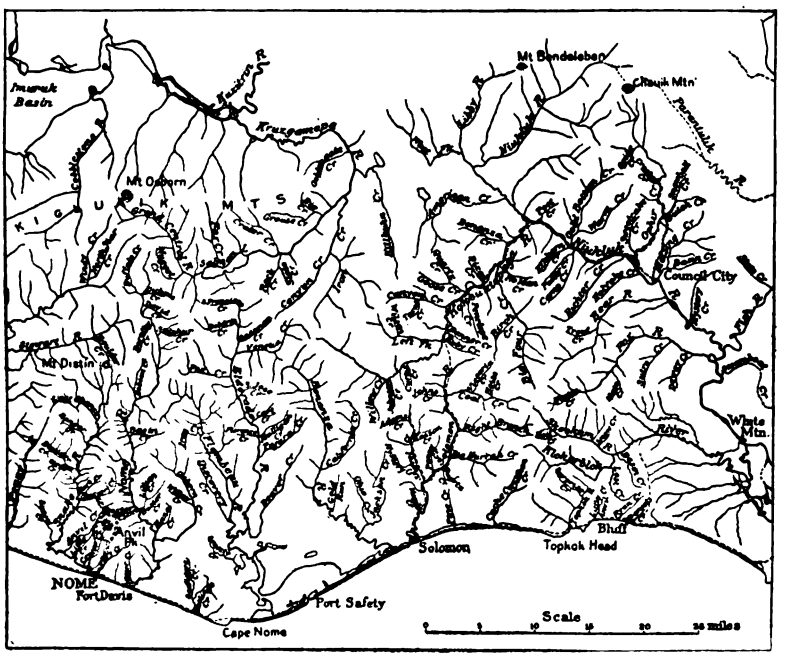



FIG. 4.—Map of part of Seward Peninsula.

Toward the north the rainfall increases in amount, and toward the south it decreases.

Table 2, giving the rainfall in Alaska, shows that there is a difference in rainfall between the coast and the interior gold districts that is too striking to need comment. Comparison of the interior rainfall may be made with that at St. Michael's station, which is the nearest point available representing Seward Peninsula conditions, yet the annual amount of rainfall at St. Michael is still very small compared with that in California.

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The accompanying tables, compiled by Cleveland Abbe, jr., on the dates of opening and closing of interior water navigation and of temperature, are here inserted because they have a direct bearing on mining operations. In general, though the fact is contrary to popular opinion, it can be stated that climatic conditions, so far as temperature is concerned, form the least of the hardships with which the miner has to contend. It is safe to say that no more generally healthy climate can be found in any portion of the known world. Data in regard to the length of season available for use of running water will be found in the tabulated list of water conduits. (See table 8, p. 104.)

TABLE 2.—*Rainfall in Alaska.*

[Compiled by Cleveland Abbe, jr.]

RAINFALL IN INCHES.

| Station. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Year. | Length of record. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | *Yr. mo.* |
| Juneau | 10.6 | 4.9 | 6.6 | 5.3 | 7.4 | 5.0 | 5.6 | 7.5 | 12.2 | 10.1 | 10.5 | 8.2 | 93.1 | 13 11 |
| Skagway | .9 | .6 | .6 | 2.4 | .8 | .6 | 1.7 | 1.5 | 3.5 | 3.2 | 2.2 | 3.8 | 21.8 | 0 30 |
| Fort Liscum | 9.7 | 1.0 | 5.5 | 4.5 | 2.3 | .7 | 4.2 | 12.4 | 14.2 | 14.3 | 6.6 | 6.0 | 81.3 | 2 0 |
| Kenai | .8 | .7 | 1.0 | .8 | 1.0 | .7 | 1.7 | 3.3 | 2.5 | 2.1 | 1.1 | .9 | 16.6 | 5 26 |
| St. Michael | .9 | .2 | .5 | .4 | 1.3 | 1.5 | 2.5 | 3.3 | 4.0 | 1.7 | 1.2 | .8 | 18.1 | 7 6 |
| Camp Davidson | .6 | .9 | .2 | .6 | .6 | 2.2 | 1.7 | 3.0 | 2.4 | .2 | .7 | .3 | [13.4] | 0 13 |
| Eagle | .4 | .6 | .4 | .8 | .8 | 1.4 | 2.2 | 2.0 | 1.1 | .8 | .6 | .5 | 11.4 | 0 52 |
| Circle | ..... | ..... | ..... | ..... | ..... | .5 | 2.0 | 2.7 | ..... | ..... | ..... | ..... | ..... | 0 5 |
| Camp Colonna | .7 | 2.1 | .8 | .1 | .6 | .3 | ..... | ..... | ..... | ..... | .4 | 1.2 | > 6.1 | 0 8 |
| Fort Adams | 1.7 | .9 | .7 | .4 | 1.5 | ..... | ..... | 2.2 | 1.5 | 2.5 | 2.3 | .8 | >15.5 | 0 26 |
| Fort Gibbon | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1.6 | .1 | 1.4 | ..... | 0 3 |
| Nulato | .7 | .9 | 1.5 | >.2 | .4 | ..... | ..... | ..... | ..... | 1.4 | 1.2 | 1.4 | > 7.5 | 0 10 |
| Anvik | 1.3 | .4 | 1.4 | .5 | .6 | ..... | ..... | 2.8 | 2.0 | 1.2 | 1.4 | ..... | >11.7 | 0 26 |
| Copper Center | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1.1 | .7 | 2.0 | 1.5 | .2 | > 5.3 | 0 5 |
| Dawson, Y. T.[a] | .7 | .4 | .2 | .78 | .58 | 1.71 | ..... | ..... | ..... | 1.25 | .45 | .65 | ..... | 0 19 |

[a] Authority: Inspector of Fisheries, Yukon Territory.

NUMBER OF RAINY DAYS.

| Station. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Juneau | 18.1 | 11.2 | 18.7 | 15.0 | 16.7 | 14.6 | 15.5 | 15.6 | 18.4 | 19.8 | 18.4 | 19.8 | 201.8 |
| Skagway | 7.5 | 2.5 | 3.0 | 10.5 | 4.7 | 5.0 | 5.7 | 8.5 | 13.5 | 12.0 | 8.0 | 11.7 | 92.6 |
| Fort Liscum | 17.5 | 5.0 | 14.5 | 9.0 | 9.0 | 8.0 | 14.5 | 28.5 | 22.5 | 22.0 | 11.5 | 13.0 | 175.0 |
| Kenai | 5.3 | 4.4 | 7.4 | 6.4 | 6.4 | 5.1 | 8.9 | 13.4 | 11.7 | 10.0 | 7.4 | 6.0 | 92.4 |
| St. Michael | 8.1 | 5.5 | 7.4 | 7.8 | 9.1 | 10.4 | 13.6 | 16.7 | 18.5 | 11.4 | 11.4 | 6.9 | 126.8 |
| Camp Davidson | 16.0 | 14.0 | 6.0 | 9.0 | 7.0 | 11.0 | 14.0 | 16.0 | 16.0 | 6.0 | 13.0 | 7.0 | [151.0] |
| Eagle | 6.2 | 5.8 | 4.8 | 8.6 | 6.5 | 9.5 | 13.0 | 13.0 | 9.8 | 7.8 | 7.0 | 5.7 | 97.7 |
| Circle | ..... | ..... | ..... | ..... | ..... | 4.0 | 8.5 | 9.0 | ..... | ..... | ..... | ..... | ..... |
| Camp Colonna | 14.0 | 16.0 | 12.0 | 4.0 | 4.0 | 5.0 | ..... | ..... | ..... | ..... | 8.0 | 14.0 | > 75.0 |
| Fort Adams | 11.0 | 8.6 | 13.0 | 3.5 | 12.0 | ..... | ..... | 16.0 | 14.0 | 16.0 | 12.5 | 10.0 | >116.0 |
| Fort Gibbon | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 17.0 | 2.0 | 14.0 | ..... |
| Nulato | 5.0 | 7.0 | 12.5 | >2.0 | 4.0 | ..... | ..... | ..... | ..... | 8.0 | 6.0 | 8.0 | > 52.5 |
| Anvik | 15.6 | 6.0 | 15.3 | 7.6 | 7.0 | ..... | ..... | 13.0 | 11.0 | 12.6 | 13.3 | ..... | >101.4 |
| Copper Center | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 12.0 | 7.0 | 8.0 | 4.0 | 2.0 | ..... |

Numbers in [ ] are totals made up from months in different year
Numbers preceded by > are known to be too small.

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TABLE 3.—*Average dates of last spring and first fall frosts.*

[Computed by Cleveland Abbe, jr. Dates marked (?) are from a single observation.]

| Place. | Last killing frost. | Last spring frost. | First fall frost. | First killing frost. |
|---|---|---|---|---|
| Juneau | (?) | Apr. 15 (?) | Sept. 20 | Sept. 20 |
| Skagway | Apr. 10 (?) | June 1 (?) | Aug. 30 | Sept. 5 (?) |
| Fort Liscum | (?) | (?) | (?) | Sept. 29 |
| Kenai | (?) | June 15 | Aug. 15 | Aug. 30 |
| St. Michael | June 1 (?) | (?) | Sept. 15 | Sept. 30 (?) |
| Point Hope | (?) | (?) | Sept. 13 (?) | Oct. 15 |
| Camp Colonna | (?) | Apr. 30 (?) | (?) | Oct. 15 (?) |
| Camp Davidson | June 15 (?) | (?) | (?) | Aug. 15 (?) |
| Eagle | May 10 (?) | (?) | Sept. 1 (?) | Sept. 2 (?) |
| Circle | (?) | (?) | Aug. 20 (?) | Nov. |
| Fort Yukon | (?) | (?) | Sept. 30 (?) | Oct. 1 (?) |

TABLE 4.—*Average dates of opening and closing of Yukon and Kenai rivers.*

[Dates marked (?) are from a single observation.]

| Place. | Ice breaks. | River clear. | Ice running. | River closed. |
|---|---|---|---|---|
| Yukon River: | | | | |
| Fort Reliance | May 10 | (?) | Oct. 20 | Nov. 5 |
| Eagle | May 11 | May 15 | Oct. 5 | Nov. 10 |
| Circle | May 13 | (?) | (?) | (?) |
| Fort Yukon | May 15 | May 20 | Oct. 3 | Oct. 26 |
| Fort Gibbon | (?) | (?) | Oct. 25 (?) | Nov. 6 (?) |
| Tanana | May 15 | May 20 | Oct. 15 | Nov. 6 (?) |
| Nulato | May 20 | (?) | (?) | Oct. 20 |
| Anvik | May 15 | May 22 | Oct. 25 | Oct. 31 |
| Kenai River: | | | | |
| Kenai | Mar. 18 (?) | Mar. 29 (?) | Dec. 5 (?) | Dec. 15 (?) |

TABLE 5.—*Table of temperatures, Fahrenheit.*

| Station. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Length record. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | *Yrs. Mos.* |
| Juneau | 34.2 | 33.0 | 37.2 | 41.9 | 46.9 | 51.6 | 54.4 | 56.6 | 52.3 | 45.7 | 39.8 | 36.0 | 5 a18 |
| Valdez | 23.8 | 15.5 | 30.8 | 31.6 | 39.4 | 49.6 | 50.5 | 46.6 | ..... | ..... | 22.4 | 21.6 | 0 10 |
| St. Michael | 7.4 | −2.3 | 8.9 | 19.9 | 33.1 | 46.3 | 53.6 | 51.9 | 43.9 | 30.5 | 15.6 | 4.8 | 11 a12 |
| Eagle | −24.8 | −6.0 | 13.0 | 29.3 | 42.2 | 52.6 | 56.9 | 49.1 | 40.4 | 20.1 | −10.0 | −7.4 | 1 0 |

a Nonconsecutive months.

## STREAM VOLUMES.

### THE MINER'S INCH.

Before discussing the matter of stream volumes it will be necessary to consider the unit of measurement, the "miner's inch," which has received so many varying definitions in different mining districts.



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On this subject[a] Mr. Hamilton Smith makes the following statements:

Soon after the discovery of gold in California in 1848 associations or incorporated companies were formed for the purpose of building ditches and storage reservoirs for the supply of water to the placer mines. The amount of capital invested in these hydraulic works aggregated many millions of dollars, and a single company often sold water to hundreds of mining claims. The cost of water was by far the most important item in the miner's bill of costs, and hence it became necessary to have a standard measure, not only accurate but also so simple that the amount of discharge could be readily computed by the common miner.

This was accomplished by the discharge of the stream of water sold to each customer through a rectangular, square-edged, vertical orifice, with free discharge into the air and having a constant head. In different parts of the State the standard opening varied, the width varying from 2 to 4 inches and the head above the top of the opening from 4 to 7 inches. Each square inch of the opening was called "a miner's inch;" hence in a locality where the standard opening was 2 inches wide, if the miner wished a flow of 50 miner's inches, the orifice was 25 inches long, and if only 10 inches was needed the length was reduced to 5 inches.

This method is analogous to the pouce d'eau used in southern France, and was probably first introduced or suggested in California by some French or Mexican miner; the simplicity of this mode of measurement, combined with a sufficient degree of accuracy, soon brought it into general use on the Pacific coast wherever water was sold for mining, irrigation, etc.

The standard which had been in use since 1852 or 1853 in the mining districts supplied by the Eureka-Lake, Bloomfield, and Milton water companies in Nevada County, Cal., was an opening 50 inches long, 2 inches wide, with constant head above opening of 6 inches; the flow from this was called 100 miner's inches. * * * Generally the miners bought water for ten hours per diem at an agreed price per inch; for example, a miner using 350 miner's inches, for ten hours each day, at the rate of 15 cents per inch, paid the water company $52.50 per diem, and received the amount of water which would flow through an orifice having an aggregate length of 175 inches, a width of 2 inches, with a head of 6 inches above the top of the opening, during a period of ten hours.

When water was used for the whole twenty-four hours of the day the flow was termed "a miner's 24-hour inch," and, of course, meant 2.4 times the amount of discharge of "a miner's 10-hour inch."

In California, as larger amounts of water came into use, wider openings were adopted, one being 12 inches high, 12¾ inches long, with a constant head of 6 inches above the top of the opening.

Experiments made in California by A. J. Bowie, esq.,[b] to determine the value of the miner's inch, defined as the one two-hundredth part of the quantity of water which would flow through the last-named aperture in a 1½-inch board under head of 6 inches above the top of the discharge, showed that 1 miner's inch discharged in—

| | Cubic feet. |
|---|---|
| 1 second | 0.02499 |
| 1 minute | 1.4994 |
| 1 hour | 89.9640 |
| 24 hours | 2,159.1460 |

[a] Hydraulics, 1886, p. 277.

[b] Bowie, A. J., jr., A Practical Treatise on Hydraulic Mining, 1885, p. 126

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Experiments on a single aperture of this form, used in determining the North Bloomfield standard made by Hamilton Smith, jr.,[a] gave a discharge (a mean of two different openings) of 302.7 cubic feet per minute, or 2,179.4 cubic feet per miner's inch in twenty-four hours.

The miner's inch used in this report is one two-hundredth part of the amount of water which will flow through an opening 12 inches high by 12¾ inches wide in a 1¼-inch plank, under a constant head of 6 inches above the top of the discharge. This may be taken for all practical purposes as equivalent to 1.5 cubic feet of water per minute, or, in other words, 1 cubic foot per second equals 40 miner's inches.

A simple means of ascertaining the approximate number of miner's inches in an open conduit is to select a straight portion of the ditch or flume where the water runs quietly and where no accelerated velocity has been imparted to it. One hundred and ten feet measured along the bank should be called 100 feet. Floats made by weighting empty cartridge shells with shot or small stones and fitting into them cylindrical wooden plugs 4 or 6 inches long are then placed in the canal as quietly as possible. Note the average time which it takes several of them to traverse the distance, divide the distance in feet by the average time in minutes, and the result will be the velocity in feet per minute; this multiplied by the area in square feet will give the number of cubic feet of water flowing per minute. To get the number of miner's inches, multiply the cubic feet per minute by 2 and divide by 3.

California,[b] Colorado, and Montana have, by State law, made the definitions shown below:

*Value of second-foot (=cubic foot per second) in miner's inches.*

| | Miner's inches. |
|---|---|
| California | 40.0 |
| Colorado | 38.4 |
| Montana | 40.0 |

The measure is of great value and should be defined by Federal law, since at present it is used in an indefinite sense. The placer miner generally assumes, when he is buying water, that he is getting 1.5 cubic feet per minute for each inch, or the inch measured under 6-inch head above the top of the discharge, whereas, in reality, the inch sold him is equal only to 1.2 cubic feet per minute, being measured under a head of 4 inches above the center of an orifice 2 inches wide.[c]

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[a] Hydraulics, p. 282.

[b] Stover, A. P., California Journal of Technology, quoted in Eng. and Min. Jour., May 26, 1904.

[c] The legal definition of the miner's inch in use in the Yukon Territory, as given to the writer by Mr. A. J. Beaudette, the Government mining engineer, is one-twelfth the amount of water that will go through an orifice 2 inches high by 6 inches wide under a constant head of 6½ inches above the center of the orifice.

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## TABLE OF STREAM VOLUMES.

Table 6, below, showing stream volumes in miner's inches, represents an attempt to combine at least approximate data relating to the amount of water which flows in northern auriferous streams during the open season. The few gagings that were made during the course of the trip were by Price current meter. It was found that variations from day to day in all parts of the country were exceedingly frequent, the volume on one day being sometimes from one-third to one-half that of the succeeding day after rain. Where a range between two amounts is given, the smaller figure may be taken as representing the most frequent condition.

TABLE 6.—*Approximate stream volumes, in miner's inches.*

| District and stream. | Gagings. | Volumes in miner's inches. | Time. | Authority. | Remarks. |
|---|---|---|---|---|---|
| Juneau district: | | | | | |
| Gold Creek | | 500–20,000 | Open season. | This report | Low to flood. |
| Atlin district: | | | | | |
| Pine Creek | | 4,000–8,000 | do | do | |
| Spruce Creek | | 1,000 | do | do | |
| McKee Creek | | 500–2,000 | do | do | |
| Boulder Creek | | 1,000 | do | do | |
| Birch Creek | | 500–15,000 | do | do | |
| Klondike district: | | | | | |
| Klondike River | | 55,000–300,000 | do | Canadian government engineer. | |
| Bonanza Creek | | 68–17,641 | do | do | |
| Eldorado Creek | | 820 | do | do | Above mean. |
| Hunker Creek | | 156 | do | do | Low. |
| Bear Creek | | 65 | do | do | |
| Dominion Creek | | 400 | do | do | Mean. |
| Sulphur Creek | | 300 | do | This report | Do. |
| Gold Run | | 120 | do | Canadian government engineer. | Below mean. |
| Eagle district: | | | | | |
| American Creek | 868 | | July | This report | Below forks. |
| Discovery Fork | 220 | | do | do | |
| Circle district: | | | | | |
| Birch Creek | | 70,000 | | do | |
| Deadwood Creek | 582 | | July | do | |
| Mastodon Creek | 322 | | do | do | |
| Mammoth Creek | | 600 | | do | |
| Junction of Eagle Creek and Mastodon Fork. | 255 | | July | | |
| Rampart district: | | | | | |
| Minook Creek | | 1,000–10,000 | Open season. | Members of Geological Survey. | |
| Little Minook Creek | | 50–1,000 | do | do | |
| Little Minook Jr. Creek | | 0–200 | do | do | |
| Hunter Creek | | 600–4,000 | do | do | |
| Hoosier Creek | | 500–3,000 | do | do | |
| Ruby Creek | | 200–2,000 | do | do | |
| Slate Creek | | 200–2,000 | do | do | |
| Eureka Creek | | 100–1,000 | do | do | |
| Pioneer Creek | | 200–1,000 | do | do | |

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TABLE 6.—*Approximate stream volumes, in miner's inches*—Continued.

| District and stream. | Gagings. | Volumes in miner's inches. | Time. | Authority. | Remarks. |
|---|---|---|---|---|---|
| Rampart district—Cont'd. | | | | | |
| Glen Gulch | | 0–500 | Open season. | Members of Geological Survey. | |
| Gold Run | | 10–200 | do | do | |
| Rhode Island Creek | | 50–500 | do | do | |
| Seattle Creek | | 50–500 | do | do | |
| Omega Creek | | 25–500 | do | do | |
| Thanksgiving Creek | | 10–500 | do | do | |
| Fairbanks district: | | | | | |
| Fairbanks Creek | 117 | | August | This report | Low water. |
| Cleary Creek | 400 | | do | do | After rain. |
| Wolf Creek | | 25 | do | do | |
| Chatham Creek | 10 | | do | do | |
| Pedro Creek | 110 | | do | do | Below Twin Creek. |
| Gold Stream | 450 | | do | do | Junction of Gilmore and Pedro. |
| Nome district: | | | | | |
| Anvil Creek | | 100–400 | Open season. | Members of Geological Survey. | |
| Glacier Creek | | 300–1,000 | do | do | |
| Dexter Creek | | 2–200 | do | do | |
| Nome River | | 12,000–20,000 | do | do | |
| Snake River | | 8,000–18,000 | do | do | |
| Bourbon Creek | | 10–100 | do | do | |
| Dry Creek | | 25–500 | do | do | |
| Osborn Creek | | 500–2,000 | do | do | |
| Buster Creek | | 100–1,000 | do | do | |
| Basin Creek | | 250–2,000 | do | do | |
| Rock Creek | | 10–50 | do | do | |
| Council district: | | | | | |
| Ophir Creek (mouth) | | 3,000–20,000 | do | do | |
| Melsing Creek | | 200–1,000 | do | do | |
| Crooked Creek | | 50–200 | do | do | |
| Warm Creek | | 100–500 | do | do | |
| Gold Bottom Creek | | 800–4,000 | do | do | |
| Mystery Creek | | 100–500 | do | do | |
| Solomon district: | | | | | |
| Solomon River | | 6,000–50,000 | do | do | |
| Big Hurrah Creek | | 500–2,000 | do | do | |
| Shovel Creek | | 1,000–5,000 | do | do | |

## GRADES OF STREAMS.

No subjects are of greater importance for the consideration of the placer miner than the grade available for moving his gravel and the vertical space which he can obtain for a tailings dump. Neglect to carefully consider the natural grade of the ground on which the proposed operation is to be undertaken will generally result in financial failure.

Alaska is not characterized by steep grades in the parts which are rich in alluvial gold. In fact, with the exception of the relatively small placer districts of the South Coast province, the long-continued

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conditions of erosion have produced surprisingly low gradients in the streams. Table 7, below, gives the grades of streams in the gold-producing districts of the north. For the sake of showing the defects of Alaska in the important requirements of grade, the lowest figure in the table gives what is frequently referred to by gravel miners as "sluice-box grade." If the sluice boxes are carried on a grade lower than 6 inches to the 12-foot box, the gravel can not be economically moved through it except by employing an excessive quantity of water. By comparing the sluice-box grade with those of the various Alaska creeks, it becomes evident that in nearly every case the material, either before entering or after leaving the tail sluice, must be artificially elevated in order that the sluice may have sufficient grade. The various devices in use for accomplishing this elevation will be discussed under proper headings.

TABLE 7.—*Stream grades along important sections of their courses.*

| | Average fall in feet per mile. |
|---|---|
| JUNEAU DISTRICT: | |
| Gold Creek | 292 |
| NIZINA DISTRICT: | |
| Dan Creek | 200 |
| ATLIN DISTRICT: | |
| Pine Creek | 50 |
| McKee Creek | 430 |
| KLONDIKE DISTRICT: | |
| Eldorado Creek | 50 |
| Bonanza Creek | 45 |
| Gold Run | 50 |
| FORTYMILE DISTRICT: | |
| Wade Creek | 75 |
| Chicken Creek | 80 |
| Walker Fork | 100 |
| EAGLE DISTRICT: | |
| American Creek | 90 |
| CIRCLE DISTRICT: | |
| Deadwood Creek | 70 |
| Mastodon Creek | 75 |
| Mammoth Creek | 60 |
| Eagle Creek | 100 |
| FAIRBANKS DISTRICT: | |
| Fairbanks Creek | 75 |
| Chatham Creek | 250 |
| Cleary Creek | 60 |
| Pedro Creek | 65 |
| RAMPART DISTRICT: | |
| Little Minook Creek | 90 |
| Hunter Creek | 75 |
| NOME DISTRICT: | |
| Anvil Creek | 100 |
| Glacier Creek | 50 |
| Dexter Creek | 120 |

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| | Average fall in feet per mile. |
|---|---|
| COUNCIL DISTRICT: | |
| Ophir Creek | 25 |
| Melsing Creek | 50 |
| SOLOMON DISTRICT: | |
| Solomon River | 20 |
| Shovel Creek | 90 |
| AVERAGE SLUICE-BOX GRADE | 220 (or 6 inches to 12 feet). |

## OPEN-CUT MINING.

### INTRODUCTION.

Under this heading will be discussed the various methods of mining by which gravel is taken out of open cuts—either simple pick-and-shovel methods or methods involving the use of mechanical contrivances. Hydraulic methods will be considered in a later section. The simplest of the open-cut methods dominated throughout the province up to within a few years, to the practical exclusion of all others except winter drifting, which will be considered below. To-day probably 60 per cent of the placer-mining operations in Alaska are confined to

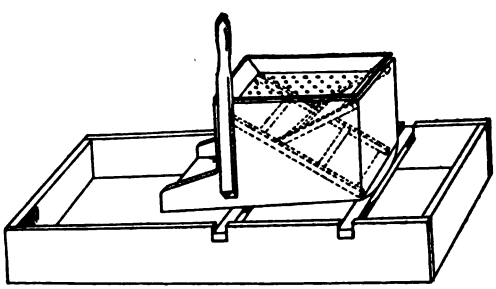


FIG. 5.—Klondike rocker.

open-cut methods, and this investigation has brought the proof that, when combined with proper mechanical devices, these form often the most economical mode of exploitation.

Open-cut methods can be conveniently grouped under various headings, but the underlying principle of excavating and transporting the material to the washing apparatus, either by hand labor or by some mechanical means, remains the same. It therein differs from hydraulic mining, where the gravel is moved by water under pressure. There are, of course, various intermediate processes, which will not require separate consideration.

### ROCKER AND LONG TOM.

The simplest method of work which the miner adopts after he has passed the stage of panning is that of shoveling from the bank and washing the gravel in a rocker. The use of the rocker is too well known to need description. The form employed in the Klondike, where its use has been nearly discontinued in mining, is shown in

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fig. 5. Two men are necessary to use the rocker properly, while only 3 to 5 cubic yards of gravel can be washed in ten hours.

At no place was the long tom seen in use in the north, although it was formerly employed to some extent in washing the Nome beach placers.

## SHOVELING INTO SLUICE BOXES.

### CONDITIONS FOR SHOVELING.

Conditions throughout many of the northern placer districts favor this well-known, simple, and cheaply installed method of placer mining, for in many localities the pay streaks are thin, ranging from 2 to 4 feet in thickness, rarely exceeding 5 feet. It is often applicable where conditions of transportation prohibit the installation of more elaborate plants.

When the total depth to the bottom of the pay streak does not exceed 12 feet, the overlying barren material can generally be "ground sluiced" off, even where the grade does not exceed 1 per cent, at an expense varying from 7 to 20 cents per cubic yard. The frozen muck which composes this overburden is from 50 to 75 per cent water, and the solid residue of silt or fine clay is easily carried away at any time of slight rise in the stream. The method of ground-sluicing the muck is described under the heading "Hydraulic mining," on page 141. Pl. IV, *A*, shows the ordinary method of setting up a string of sluice boxes on a creek placer. This method is used in an elaborate form on Anvil Creek, where 5 strings of boxes and 120 shovelers give a twenty-hour capacity of 1,080 cubic yards.

The handling of the water is important. Even when the gravel has been solidly frozen previous to stripping and sun thawing, there are generally from 15 to 25 miners' inches of seepage water, which work into the pit floor. This must be disposed of either by draining or by pumping. If sufficient water (50 miners' inches) is available, a "China pump" can be rigged up, as shown in Pl. IV, *B*. This device is not economical in its use of water, for the water is generally of more value for other purposes in Alaska mining.

### DAMS.

As in all other forms of creek mining, great care must be taken to keep the creek water out of the working pits by means of dams. Dams constructed of sod walls lined with sacks have been found cheaper in the Klondike than those built of sod and brush. Pile driving is not advisable in the north, but in case timber is abundant cribbing is desirable, as illustrated in Pl. V, *B*, showing a dam built across Discovery Fork of American Creek to impound water for "booming." The ends of the logs were set in frozen ground on both sides and the muck was allowed to refreeze around them. The dam, 40 feet long, consists of 12-inch timbers, from 9 to 18 feet long, laid up in two rows, 5 feet apart, earth and rock filled, and braced with

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*A*. SET-UP OF BOXES FOR SHOVELING-IN, AMERICAN CREEK.



*B*. CHINA PUMP, KLONDIKE.

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cross timbers as indicated. The dam, self-dumping gate, and accessory flumes were built by two men, and are said to have cost, in labor and time, only $300.

The self-dumping gate shown in Pl. V, *B*, was not in use when the visit to Discovery Fork was made. It had been used during the month of June, 1904, in "booming" the overburden from the area of pay ground which it was desired to uncover. The action of the gate is apparent from the illustration. Swinging on its horizontal axle, set two-thirds the distance from the top to the bottom of the gate, it releases the water when the reservoir becomes full and regains its closed position when the reservoir is nearly empty. During a period of three weeks a block of overburden consisting of muck and barren gravel, 5 feet thick by 25 feet wide by 900 feet in length, had been removed by the booming process before the shoveling operations commenced, the total cost, including the construction of the dam and gate, not exceeding 7 cents per cubic yard.

The process of booming by means of automatic water gates was formerly generally in use in California, and is employed even to-day in southern Oregon. Pliny mentions the process as having been in extensive use in Spain before the Christian era. As a rule it is inapplicable to mining or stripping in Alaska, because the stream grades are gentle and because the débris carried down by the torrential stream will damage property situated farther down the creek.

On Hunker Creek, in the Klondike, a dam of moss, brush, and gravel, 90 feet long and 18 feet high, built for the purpose of keeping the water from an open cut, cost $500. Dams in Seward Peninsula are successfully built of sod, the material which overlies the frozen muck to the depth of 2 feet. Sacks of sand are also successfully used.

### DRAINS.

Below the proposed pit a backwater dam, generally 4 feet in height, is built across the creek, and the end of the sluice is extended beyond this dam a few feet. Pl. IV, *A* (p. 56), shows the system of damming to keep the water out of a small shoveling pit, and Pl. V, *A* (p. 58), shows backwater dam and the standpipe erected to receive water for the bed-rock drain. Assuming that the ground is to be worked upstream, the method of laying off the drain, commonly called the "bed-rock drain," is as follows: In 12-foot ground take a level and sight downstream from the prospect pit to a point where 12 feet vertical distance above the water in the stream is obtained. The sight should be taken at a point 2 feet above the surface of the ground, to allow for the height of the backwater dam. The point where the drain is to be started is the distance downstream obtained by the sight plus 12 feet, allowed as a safety factor. On a 2 per cent grade this would necessitate a drain 612 feet long. The drain is dug and left open until after the first cut is made. Its dimensions are generally

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2 by 2 feet and it is lagged inside with poles horizontally, these being held by posts with 4-foot centers, into which shoulders are cut for caps. After the first cut the drain must be covered by logs and moss laid on top of the caps. For small operations a box drain made of sawed 1-inch lumber, the inside dimensions being 12 by 10 inches, is used. There should be a standpipe bored with auger holes in the drain at the lower end of every cut. The drain should have a very slight grade, as low as 1½ inches to 100 feet being used. At first the drain will handle only seepage water, but if one cut of 100 feet in length after another is successively worked upstream, sluice water may have to be run through it to prevent backing up. Some operators recommend keeping the main drain large and giving it the bed-rock grade, while a smaller drain, 8 by 8 inches, is kept parallel to it on a less grade. This will handle the seepage water and will gain depth upstream, thus allowing for inequalities in the bed rock, which are very frequent.

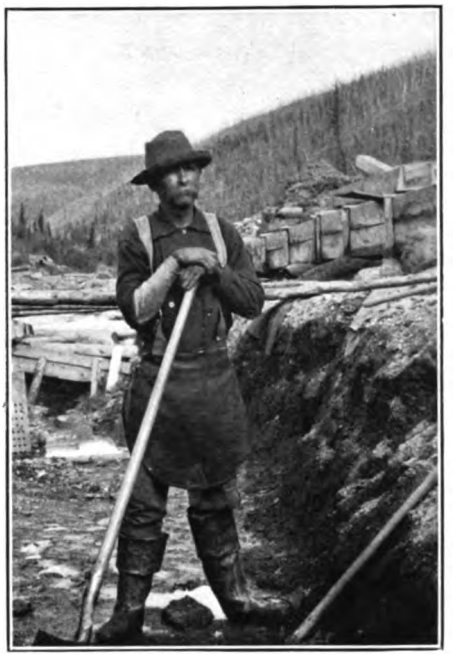
Drains are expensive to make but are generally preferable to pumps. On Mastodon Creek, in the Birch Creek district, a bed-rock drain, 500 feet long, dug 4 feet wide, lagged inside with 4-foot cord wood, making it 2 feet in the clear, and covered with poles and moss, was dug through cemented and frozen gravel and bed rock, and cost $7,000, its construction consuming all of one season. In the Fairbanks district an open drain, not lagged, 3 feet deep and 3 feet 6 inches wide, took the labor of 2 men six weeks, costing nearly $900.

In excavating for drains the ground should be cut in terraces, so that when it commences to thaw it will not run and clog the canal. Pumping seepage water from the pit is to be condemned in general as strongly as pumping water for sluicing. In Bonanza Creek, Klondike, an operation involving the handling of several thousand yards was said to be more expensive by 40 cents per cubic yard when pumping of the seepage was done than when the water was handled by drain. The pumping of seepage water by any form of pump may be estimated to add at least 25 cents per cubic yard to the expenses of handling the gravel. The use of overshot wheels operating China pumps is cheap where water is plenty. The small one illustrated by Pl. IV, *B*, was using 20 inches of water to lift about one-third this amount a height of 10 feet. Such a pump in the Klondike, with 5-foot wheel, costs $100 to build.

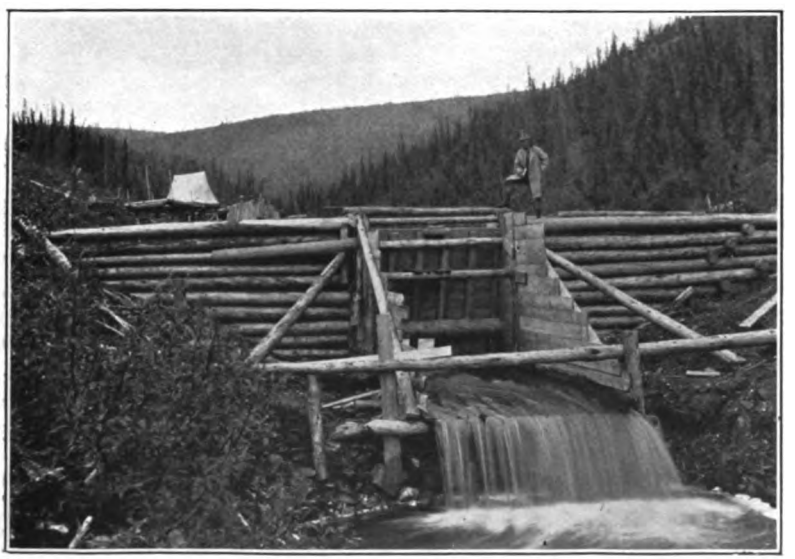
### COST OF SHOVELING.

The cost of a plant, including that of constructing a seepage-water drain, sod dams, and a string of 10 sluice boxes, with a ditch to lead the water to the sluice, varies from $500 to $2,000, according to the conditions. As stated in the cost sheet (table 1, p. 38), the expense of handling gravel by this method is from $1.25 to $2.50 per cubic yard, reaching $5 to $7 in remote districts.

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*A*. YUKON PLACER MINER.



*B*. DAM FOR BOOMING, AMERICAN CREEK.

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The duty of a man shoveling is variously estimated in different districts of the North. This form of mining having been nearly discontinued in the Klondike region, very little information concerning it was obtainable. The extensive shoveling operations on upper Bonanza Creek were not visited. In one case, where a platform was used, 2 men shoveling, in two stages, a total of 9 feet lift, 2 feet of pay were shoveled into the boxes at the rate of 3½ cubic yards per ten-hour man.

In the Birch Creek district the duty of a man shoveling from an average of 12 operations is 5 cubic yards in ten hours, the depth of pay averaging 4.41 feet, and the lift never exceeding 6 feet.

In American Creek, where the bowlders were large and men had to stop work to get them out of the way, the duty was 2¾ cubic yards. On Discovery Fork of this creek the duty was 4 cubic yards, the depth being 5 feet.

In the Fairbanks district, where shoveling-in operations are few, owing to the depth of ground, the average of three seen was 7½ cubic yards duty, the depth shoveled being 3 feet of pay, part gravel and part bed rock. In no case was there a lift of over 5 feet.

In the Nome region 5.76 cubic yards duty is probably very near the average on a bank from 5 to 7 feet in height. In the case of the large operations of the Pioneer Mining Company, on Anvil Creek, the work has been so systematized that on the 3-foot bank handled the duty is 9 cubic yards per ten-hour man.

One operation on Solomon River, where the lift was high, and the bed rock irregular, 3.75 cubic yards was the duty on a 3-foot bank.

In the Council district of Seward Peninsula, including operations on Ophir, Crooked, Warm, Gold Bottom, Camp, and Penelope creeks, the duty of a man averages 6.63 cubic yards on an average height of bank of 3.5 feet. This average is affected by one case where on a limestone bed rock, with double lift, the duty was 3.5 yards; also by another where with eight-hour shifts, working on 3-foot bank with 5-foot lift, the extraordinary duty of 12 cubic yards per man was vouched for.

The method of working shallow placers by shoveling into boxes has much to commend it, especially when the water is drained from the cut, either with or without a covered drain. In Alaskan gravels exceeding $3 in gold tenor to the cubic yard of material handled by shoveling, frequently from one-half to two-thirds of the gold lies in the crevices of the upper 18 inches or 2 feet of the bed rock. Men directly shoveling this material can thoroughly clean the bed rock by the shoveling-in method. On the other hand, if horse scrapers, steam scrapers, or steam shovels are used, the bed rock is frequently not cleaned, and a gang of men must go over the ground a second time to pick up the auriferous material which has been left. This point is

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of the first importance. No operator should contemplate the installation of mechanical excavators for working gravel without taking full account of it.

In considering methods of mining by water or mechanical power, the cleaning of bed rock by men may be permissible from an economic standpoint in exceptional instances, as, for example, where a thick overburden is cheaply removed by hydraulicking and a very thin rich pay streak remains. When, however, a mechanical method of removing overburden and low-grade gravels costs from 50 cents to $1 a yard, and the whole area has to be gone over again by men to wheel the rich pay to the sluice, the gravel must be extraordinarily rich to pay a profit. The lowest cost of handling gravel by the method of shoveling in was found to be $1 per cubic yard on one of the creeks of Seward Peninsula, while the cost may reach $5 on some of the isolated interior creeks of Alaska.[a] From 10 cents to $1 per square yard of area worked must be generally added to the shoveling cost to cover the cost of stripping muck or overburden. Ground which exceeds 12 feet in depth of combined stripping and pay will rarely pay if handled by the method of shoveling into the sluice.

### HORSE SCRAPING INTO SLUICE BOXES.

Ground which can be worked by men shoveling into sluices can, under certain conditions, be worked satisfactorily by horse scraping, and at an expense of one-third of that necessary to shovel in. The most important governing condition is the degree of looseness in the gravel and in the underlying auriferous bed rock. Two horses, or, better, mules, hauling a scraper, with driver, will cost from $17 to $23 a day, and in the ordinary small gravel of the Alaska placers, with soft schist bed rock, the team will scrape into the boxes from 30 to 40 cubic yards of gravel a day over a distance of 75 feet. On Penelope Creek, in Seward Peninsula, it was said that the team would handle as much as 10 men could shovel, the cost per cubic yard being 30 cents.

One common breaking plow with a team of horses suffices to break up enough ground for four scrapers. The method requires an inclined platform built up to a height of 10 to 15 feet above the bed rock, over the head box of the sluice. A rectangular opening in this platform serves as a chute to the dump box. Generally the horses travel in an elliptical track, passing the end of the tail box and scraping the tailings from it, then entering the pit, scraping up the pay, and afterwards delivering it to the sluice. In Seward Peninsula the cost of this method can be brought as low as 25 cents per cubic yard, and in no part of the interior will it exceed 50 cents, exclusive of top stripping.

[a] See cost sheet, table No. 1.

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Many deposits were seen now worked by shoveling into sluices where at least an experimental trial of this method is to be recommended. One of the strongest points in its favor is the cheapness of installation and the mobility of the apparatus used.

## STEAM SCRAPERS.

In view of the economical showing which the steam scraper has made in handling tailings from the creek-mining operations of the Klondike it is remarkable that so few attempts have been made with it to scrape the alluvium from its original position. The ordinary scrapers used in steam-scraping operations on tailings in the Klondike have a capacity of from one-third to one-half cubic yard, operated by double drum, 2-cylinder hoist; 16-inch drums, 25 to 30 horsepower capacity, handling on an average 250 cubic yards of loose material in twenty-four hours, at an average expense of 49 cents per cubic yard. The manipulations of the scraper, considered as a unit of the plant, take 3 to 4 men on shift—a fireman, a hoistman, and either 1 or 2 men to fill, guide, and dump the scraper. The form and rigging up of the scraper, with the system of sheaves, pulling, and drawback cables, is shown in figs. 6 and 7. In the practice seen the scrapers drag the material from the pit to the dump, a distance measured horizontally from 100 to 300 feet and vertically from 20 to 50 feet. The scrapers are not always provided with teeth like the one shown in the figure, but this is advisable. A rigid bale should never be used, as flat stones catch between it and the body of the scraper. The plants average $3,500 in cost.

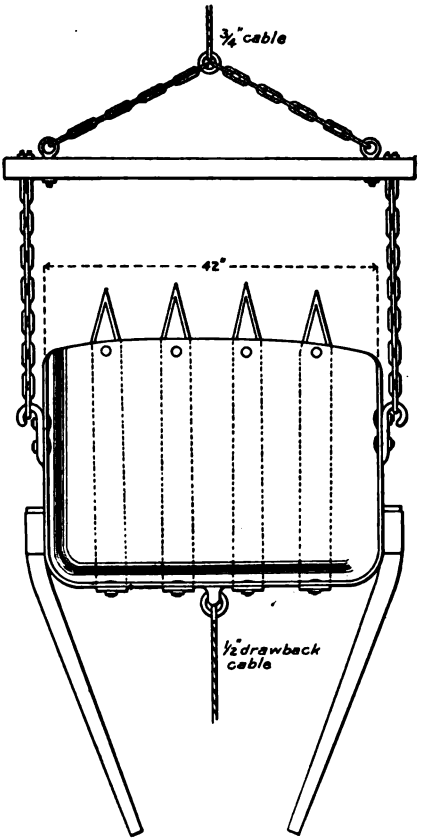


FIG. 6.—Small steam scraper, Klondike.

The rig shown in Pl. VI, *A* (p. 62), is situated on Walker Fork, Forty-mile district, Alaska, where a body of gravel 60 feet in width and 5 feet in depth, with little or no stripping, was being mined. According to information obtained by Mr. L. M. Prindle the gravel was only

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partially free, and little or no stripping was required. As a rule the scraper was found to clean the schist bed rock satisfactorily. The scraper used had a capacity of one-fifth cubic yard, being an ordinary horse scraper rigged for steam with pulling and drawback cables. A 6-horsepower hoist operated the scraper, giving a capacity of 100 cubic yards in twenty-four hours. The 10-horsepower boiler also furnished steam to operate the bucket elevator which lifted the gravel to the sluice from the hopper, to which it was dumped by the scraper. A conservative estimate places the cost of handling gravel with rig, 3

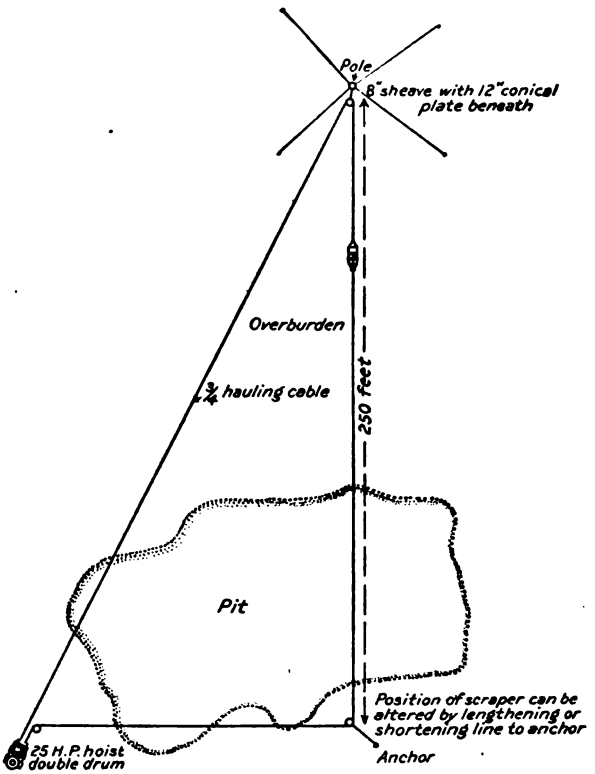



FIG. 7.—Set-up of scraper, Klondike.

men being employed and one-half cord of wood burned in ten hours, at 40 cents per cubic yard. The operations were meeting with financial success.

The plant contains the elements of a device which, it is not unlikely, may be applied to the working of the wide, shallow creek deposits of Seward Peninsula, or of such creeks of the interior as Mammoth, in the Birch Creek district, or lower Pedro, in the Fairbanks district. If circumstances warranted, the sheave anchor (a rock-filled crib) shown in Pl. VI, *A*, could be made more easily movable by mounting it on a truck running on track, it being made fast by cable and dead-

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*A.* STEAM SCRAPING ON WALKER FORK, ALASKA.



*B.* DUMPING TO SLUICES, KLONDIKE.

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man when occasion might require. The bucket elevator employed is not recommended, as the use of such contrivances for handling gravel, unless they are specially and expensively constructed—as on large dredges—is condemned by experience. In place of this, the scraper should be dragged entirely to the point of final discharge to the sluice on an inclined platform. The operation will necessitate the building of a more elevated sluice or washing plant, surmounted by a hopper, the gravel being fed from this in order that the feed may be as nearly continuous as possible. Assuming that the elevation of the head box of the sluice shown in the illustration is 12 feet above the surface of the ground, the scraper could be dragged to double this elevation at a cost not exceeding 10 per cent above that necessary to haul it up to the 12-foot elevation. One of the types of washing plants described on pages 193 et seq. would be applicable with modifications to a steam scraping plant.

It may be well to consider here the reasons why, in wide, shallow creek deposits, steam scraping appears to be preferable to other mechanical methods. In general, it may be said that this method is applicable to operations on schist bed rock, but is entirely impracticable on limestone or other hard bed rock. This is also true of the steam-shovel and dredging methods. Grant that bed-rock conditions are suitable, and consider a solidly frozen deposit of characteristic small gravel with muck and moss overburden, 150 feet width of pay and 7 feet in total depth from grass roots to bottom of pay. After the moss is plowed up, the 3 feet depth of muck can be ground sluiced off in the ordinary manner at an expense of, say, 15 cents per cubic yard. The ground sluicing should be done at the earliest possible moment in the open season or, preferably, late in the fall. The operator now has to deal with a stripped block of frozen gravel and auriferous bed rock 4 feet in depth, carrying pay, or the material which it is desired to sluice. A vertical bank of this material can not be attacked by any mechanical appliance yet devised, but if left uncovered for six weeks it will thaw to bed rock. The operator, however, wishes to take advantage of the continual thawing of the surface by the sun, and to do this he must attack not a vertical but a horizontal surface. The rate of natural thawing varies from 6 inches to 1 foot a week. The scraper armed with teeth rigged so as to make a series of transverse cuts, say for 300 feet lengthwise of the channel, will attack the ground, scraping off the thawed material better than any other mechanical appliance.

The sluice boxes or washing plant built to a height of 25 feet above the surface of the ground can now be approached by a broad incline platform, or, if desired, the scraper may dump to cars which convey the material by gravity to an isolated and conveniently situated washing plant. The system adopted will depend on the magnitude of the

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operations. In only very exceptional cases should the expense of handling, after the material is once dumped from the scraper, be allowed to exceed 5 cents to the cubic yard.

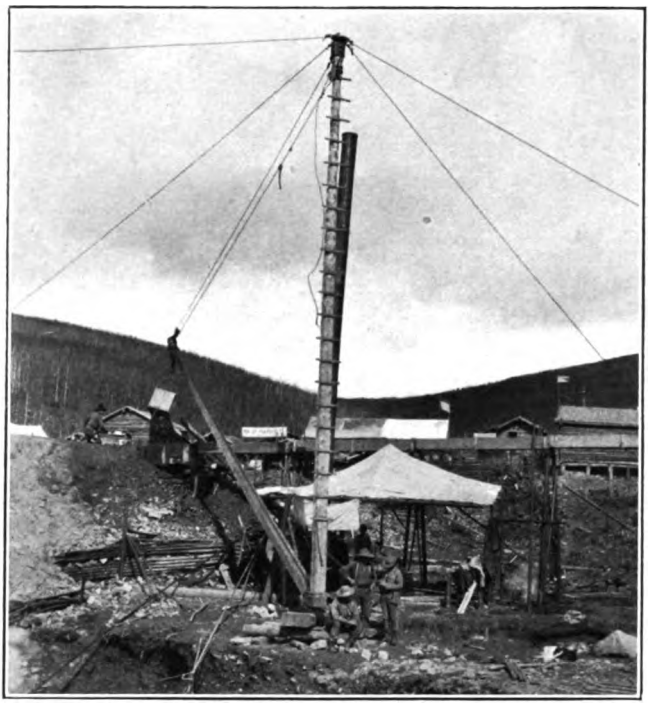
The plant above suggested implies the use of a scraper of large capacity and should handle the gravel at a total cost, including depreciation charge and added cost of stripping, not to exceed 40 cents per cubic yard in Alaska, provided that 700 cubic yards of gravel a day are sent to the sluice. In order to accomplish this a scraper, preferably of the bottomless, self-dumping type, of 6 yards theoretical capacity, should be used. It will be found that actually 3½ yards will be delivered each time by such a scraper. The operations will require a 60-horsepower boiler and double-drum hoist, and the services of seven men on a shift. The total running expense of the plant should not exceed $150 a day of 24 hours.

The double-drum hoist operating the scraper will have a position on the side of the sluice opposite that of the cut, and can be mounted on skids so that it can be easily moved by means of a sheave and deadman if necessary. The sheave through which the drawback cable runs may be anchored to a weighted car running on 200 feet of track laid parallel with the cut on the side opposite that occupied by the sluice and hoist. If it is desired to keep the drawback cable out of the way it may pass through two sheaves, one anchored to traveling anchor and one to deadman, the cables thus forming a triangular arrangement, two of whose angles will vary as the car is moved to cover various parts of the ground. The car may be moved as often as desired, and thus one furrow after another may be made by the scraper over a triangular area as the ground thaws. By means of a rearrangement of the sheaves it is found that nearly all of the ground can be covered. A plant erected for the Klamath River Gold Mining Company[a] is provided with two 1¼-yard scrapers, which travel back and forth alternately, both cables acting as pulley and drawback cables. Two sheaves are used on the side of the excavation opposite to the washing plant. "These sheaves are attached to a spreader which keeps them spaced a given distance apart, and to each end of the spreader is attached a tackle which runs back at an angle to deadmen to which they are securely anchored."

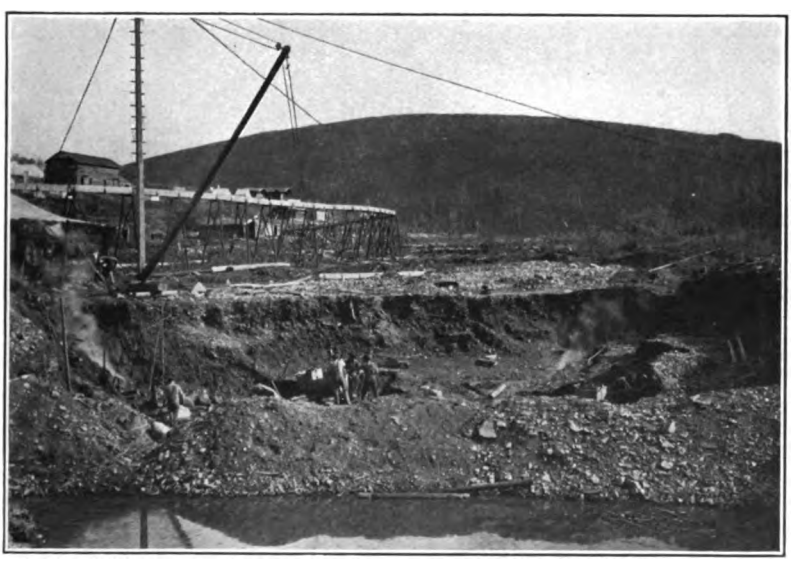
The type of bottomless scraper shown in fig. 8 (p. 65) was seen in successful operation stripping loam at a reservoir excavation near Portland, Oreg. It has a theoretical capacity of 6 yards, and actually handles a little over half this amount. Measurements of a spoil bank showed that in seven ten-hour days, stripping to 4 feet in depth, 400 cubic yards per shift had been handled. The scraper was making furrows over 300 feet in length. A 60-horsepower boiler was used,

[a] Yeatman, J. A., Automatic excavator for placer mining: Min. and Sci. Press, Dec. 17, 1904.

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*A.* DERRICKING AT FAIRBANKS, DUMPING.



*B.* DERRICKING AT FAIRBANKS, LOADING.

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but only one cord of wood at $2 per cord was burned. The double-drum hoist was provided with 10 by 12 inch cylinders and was geared 6 to 1. Four men, a winchman, a fireman, and two scraper men were employed, at $2.50 a day. It was said that under these conditions the operations cost 5 cents per cubic yard. It was estimated that in a haul of from 150 to 200 feet the scraper would deliver loam to the spoil heap at the rate of 2 cubic yards per minute.

The above suggestions regarding the use of self-dumping scrapers in northern placer mining will doubtless be looked on with considerable skepticism. No direct application of the method has, so far as known, been made in Alaska. The form of plant outlined is inexpensive as compared with many already installed in Alaska, having a capacity not exceeding 700 cubic yards. The sum of $10,000 should be ample to install an entire scraper and washing plant in Seward Peninsula. Even should some form of steam scraping be found appli-

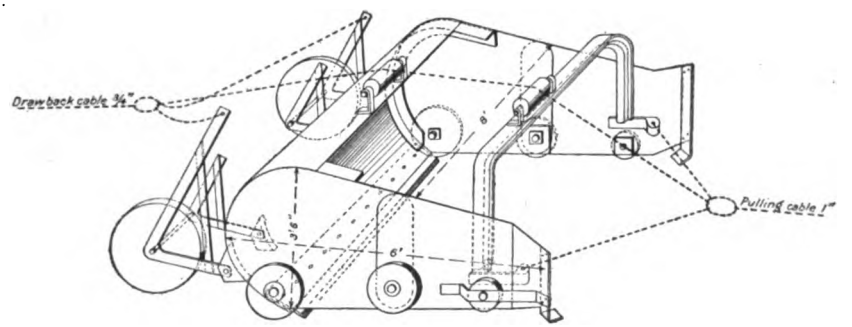



FIG. 8.—Bottomless steam scraper.

cable to the wider shallow deposits, the installation of elaborate cableways, traveling towers, and the like, is not advisable, as in most cases their cost would be prohibitory.

## SELF-DUMPING CARRIERS.

The conditions in the Klondike district appear to have necessitated the adoption of this expensive method of placer mining. Outside the Klondike field the method was not seen except at one place on Mastodon Creek, in the Birch Creek district. The method is adopted to work rich gravels where conditions do not permit working by ordinary shallow open-cut methods, and where drifting is impossible or inadvisable.

In considering the economic success of this method, a study of the cost sheet given in this report (table 1, p. 38), is most instructive. In the first place the average depth from eight Klondike operations considered, namely 17.5 feet, is greater than that economically advisable



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(namely, 15 feet) for open-cut operations in general. The operator adopts this method because there are thawed streaks and channels in his deposit. If such ground is drifted, the chances are that he will increase his expense to a prohibitive amount through excessive timbering and through pumping of seepage water, whereas by the open-cut method the water is handled by drain. The cost sheet shows that whereas $2.14 is the average cost of the above-mentioned 8 operations in the Klondike, 7 drifting operations in similar deposits, with an average depth of 25.3 feet, gave an average cost of $1.95 per cubic yard, the depth of the pay or thickness of gravel actually sent to the sluice being almost exactly the same in both cases, and the capacity in the drifting being only 17.5 cubic yards less in twenty-four hours. Granting, however, that in a given deposit carrying $3 to the cubic yard of pay, the depth being 16 feet, drifting is impossible, and the rich pay, 75 feet in width, must be worked by open cut. Whatever method be adopted the moss must first be plowed up and about 6 feet of muck ground sluiced off at a cost of 17 cents per cubic yard. Next 6 feet of barren gravel or sand must be removed, either by horse scrapers at 60 cents per cubic yard, or, if the plant warrants the operation, by steam scraper at 49 cents per cubic yard. The 4 feet of pay being laid bare, what method shall be adopted to get it into the sluices? On account of the necessarily short life of the operations, a plant whose first cost exceeds $5,000 is out of the question. The greatest expense will then result from the hand shoveling in the pit. The getting of the material into the receptacle in which it is conveyed to the sluice is the principal item of expense in the operation. It is therefore necessary that the high-priced shovelers get as much gravel into the wheelbarrows or buckets as possible. The bucket, 37 inches square on top, 35 inches square on bottom, and 25 inches deep, holding two-thirds of a cubic yard, is dropped into a crib built in the bottom of the pit, to which the shovelers wheel their dirt in wheelbarrows. From 4 to 6 wheelbarrows are necessary to fill the bucket. There is no mobility to the bucket; it must always rise and fall to the same spot. Men instead of occupying all their time in shoveling are employed nearly half of it in wheeling and dumping. Five operations are necessary to get the gravel from the bank to the sluice, namely, (1) shoveling into wheelbarrows, (2) wheeling to bucket, (3) dumping to bucket, (4) raising bucket to carrier.[a] (5) conveying and dumping to sluice. (See Pl. VI, *B*.)

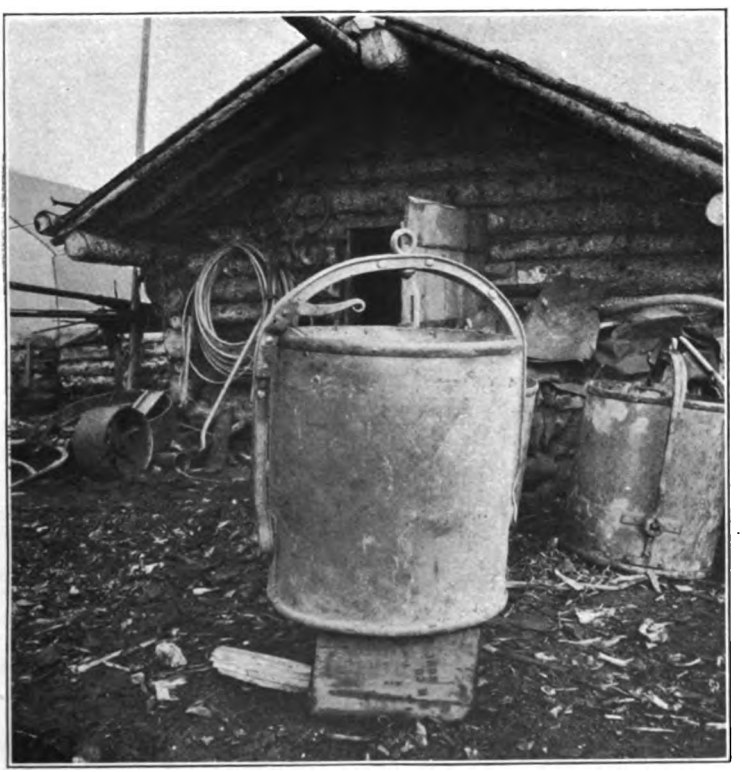
This may now be compared with the derricking system. On Pedro Creek, Fairbanks district, an open cut 15 feet of depth with 9 feet of pay gravel is worked by derricking. The plant has a capacity of 233 cubic yards a day, which is handled at a cost of $1.75 per cubic yard. The plant costs no more than the average price of a self-dumping

[a] The Dawson self-dumping carrier and its use is described under the heading "Drift mining," p. 94.

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*A.* SKIDS FOR DERRICKING.



*B.* DERRICK BUCKET.

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carrier plant of daily capacity not exceeding 200 yards. The first cost of all, including a 30-horsepower boiler, was said to be $4,500. Here the gravel is shoveled into buckets holding 8 cubic feet. These buckets are trammed on small trucks running on wooden tracks, hooked onto by the derrick cable and lifted and conveyed at same time to the sluice. The derrick boom has a radius of reach of 40 feet, and a much smaller proportion of time is consumed by the shovelers in tramming than when the fixed bucket on cable is used.[a] The expense was increased in this plant by the necessity of continually thawing with 24 points. Pl. VII, *A* and *B* (p. 64), shows the operation of the derricking plant.

As against the 5 operations of the cable tram system, there are only 3 in the derricking system if properly handled. The proof that the derricking system is superior to the wheeling and cable tram system is evident from the comparative cost. The services of a man at the dump box are generally necessary in all cases under the present sluicing practice, so that the self-dumping arrangement of the bucket helps but little.

It should be noted that the Fairbanks operator was working under higher prices generally than the Klondike miners, both for labor (at $10 a day, as against $7.50 a day) and for general supplies, and he also had an excessive amount of steam thawing. His lower cost depended primarily on his increased capacity, resulting for the most part from the increased duty of each shoveler, owing to the expeditious and adaptable system of hoisting and conveying afforded by the derrick. A derricking system in use on Seward Peninsula will be separately described.

The conclusion is that while the cable tram system, using the Dawson carrier, is excellent for drifting work, it is not to be recommended for open-cut work where it is possible to obtain space for installing a derrick.

## DERRICKING.

The plant described below is located on Ophir Creek, in the Council mining district of Seward Peninsula. The stream has been turned aside and work is proceeding in the old bed. The distinctive feature of the plant is the use of derricks in overcoming exceptional difficulties encountered in the character of the deposit. Hand labor is used in excavation, while transport of material to be washed and disposal of tailings are accomplished by derricks.

The pit in which work is being done depends for its shape and size upon the method of working and length of the derrick boom. An area of 30 feet beyond the end of the derrick boom is worked. A pit, roughly circular, having a diameter of 140 feet, is the result, since the

[a] See also special description of derricking, pp. 67-71.

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boom reaches approximately 40 feet in its sweep, and the buckets are hauled 30 feet from the bank. Under a stratum of sand and soil, varying from 4 to 5 feet in thickness, the gravel, in places considerably mixed with sand and clay, descends to bed rock, usually 30 feet below the surface. The gravel is entirely unfrozen, rounded, and for the most part small, not over 10 per cent exceeding 6 inches in diameter, while no bowlders are found above 18 inches. Bed rock is a massive limestone, extremely irregular in its position, and causes the greatest difficulty in the extraction of much of the gold, though this same feature must have played an important part in the enrichment of the claim. (See Pl. VIII, *A*, p. 66.) In places deep holes have been made by action of water, and the depth to which work is carried in the recovery of the gold depends entirely upon the economy with which it is extracted. There is no doubt that much gold remains below, to obtain which would not be profitable under present conditions.

Excavation is accomplished entirely by pick, the gravel being shoveled into the derrick buckets. These buckets are hauled by the derrick line, guided by hand, upon wooden skids (see Pl. VIII, *A*), to a point directly beneath the end of the boom, where they are hoisted and carried to the dump box.

The buckets are of 11 cubic feet capacity, and are so practical as to warrant detailed description. They are made of crude oil drums or gasoline tanks, cut to a height of 2 feet 8 inches, and are 2 feet 5 inches across the top. (See Pl. VIII, *B*.) Two lugs to hold the bale are set opposite each other one-fourth distance up from the bottom. The bale is made from the original hoops of the drum. The bottom edge is strengthened by the original flange of the tank, while on the upper edge has been riveted the flange originally at the top of the tank. The bale is supplied with a catch which, when the bucket is traveling, rests in a notch constructed on its edge, which holds the bucket in an upright position. On reaching the dump box, a man on the platform with his shovel frees the catch, and the bucket dumps in turning bottom upward. (See Pl. IX, *A*.) In fitting the lugs holding the bale, a piece of iron 9 inches square is riveted to the inside of the material composing the drum, which is one-eighth of an inch thick. To the outside of the drum a strip 9 inches long, 2½ inches wide, and one-half inch thick is also riveted, and to this the lug (2 inches long) is welded, making a very strong construction. These buckets weigh 140 pounds and, including labor, blacksmith fuel, and original price of drum, cost about $25.

The skids upon which the buckets are hauled are ordinary smoothed timbers, and are not fastened down. This admits of rapid change in accommodating the hauls to the advancing work. It is desirable to have these timbers as much as possible in a radius of the circle described by the derrick, as this gives a straight haul on the boom.

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*A.* DUMPING BUCKET.



*B.* ROUGH BED ROCK AND BOWLDERS PILED IN PIT.

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The derrick in use at this plant is of a very simple and practical design, there being but one haulage line, which with gravity utilized in the lean of the derrick accomplishes the desired work. The derrick leans toward the pit in which excavation is taking place—i. e., when at rest the boom swings away from the hoisting engine. (See Pl. X.) The hauling line passes through a block at the foot of the mast and a few feet in front of it, or toward the direction of haul. In this position immediately upon receiving a hauling strain the boom tends to move toward the dump box, and once there, having disposed of its load, returns by gravity to the pit. To the end of the boom is attached a rope by which a man in the pit giving his entire attention to this operation can regulate the swing of the boom to a nicety. By snubbing this line about a post set firmly in the ground, hauls can be made in any direction with no inconvenience from the swinging of the boom, and the dumping of the load on the platform can be accurately adjusted. The derrick on an average lift raises material about 25 feet and carries it approximately 85 feet to the sluices. The amount of material handled is generally 500 cubic yards in twenty-two hours. Power is obtained from a 15-horsepower boiler and 8-horsepower double engine hoist, which burns one-half cord of wood in twenty-four hours at $15 a cord. The derricks are of Washington fir, both boom and mast being 40 feet long. The hauling line, one-half inch in diameter, is of crucible steel wire, plow-share steel not bending easily enough, and the guy lines, three-eighths inch in diameter, also of steel, are tightened by watch tackles.

Stones over 12 inches in diameter are not sent through the sluices, being piled by hand in the center of the pit. Larger stones and bowlders of bed rock are handled by the derrick and piled in the same manner. (See Pl. IX, *B*, p. 68.) The removal, however, of stones exceeding 2 tons in weight is not attempted with the derrick. A move is necessary each thirty days, and in advancing the entire plant approximately 110 feet eighteen hours are generally consumed. An auxiliary flume and dump box must of necessity be used to permit such rapid change.

The dump box, which is furnished with a platform sufficiently large to prevent spilling of material, is from 6 to 12 feet above the ground. It is 16 feet long and has a grade of 14 inches. Below it are 132 feet of boxes, 20 inches deep and 16 inches wide, with a grade of 7 inches to the box length (12 feet). These are furnished with pole riffles made 2 inches square, capped with iron, and will last two seasons. At the end of the string is a very efficient undercurrent, invented on the ground. It consists of an ordinary sluice box furnished with iron bars approximately three-eighths or one-half of an inch in diameter, running lengthwise with the box and placed side by side. Beneath these bars, held by Hungarian riffles, is a quantity of quicksilver,

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which catches any gold that may have passed the preceding string. Such an arrangement, though of considerable use when gold is generally coarse, will not serve when fine gold is encountered. An undercurrent of greater surficial area and greater grade, carrying the water in a thin sheet, would then be demanded.

In washing the gravel 150 miner's inches are used. The water is brought from Ophir Creek in a ditch 1¼ miles long. It is 6 feet on the bottom, 9 feet on top, and has a grade of one-tenth inch to 100 feet. It cost $8,000.

Tailings are handled by a derrick and a self-dumping scraper. Power is supplied to the latter by hauling directly from the derrick boom, and its operation is directed by two men. In this case the derrick leans toward the dump pile, to which it carries its load by gravity, being hauled back by the steam winch. To the scraper is attached a rope which, on tightening as the derrick swings, dumps the load at its destination. (See Pl. X.) Both the derrick boom and mast are 40 feet long and are arranged like the excavation derrick, except that the mast leans in the opposite direction. A 15-horsepower boiler and 8-horsepower winch are used, and there are three men on each shift. The tailings derrick is not occupied more than one-fourth the working time of the pit derrick.

In all from 55 to 60 men are employed about the plant. A man is continually needed at the mud box to trip the bucket and to feed the gravel as regularly as possible to the sluices from the platform. A winch man is needed at each derrick. A man in the pit devotes his entire attention to the snubbing line, while two men are necessary on the scraper. The latter feature could possibly be improved by some mechanical method not requiring the hand labor. Wages are 50 cents an hour, with board, and work is continued eleven hours each shift.

Besides the derrick plant above described another, seen on Ophir Creek, made use of iron skips of 1¼ cubic yard capacity, which were run on trucks to the working face and, after loading, were trammed within reach of the derrick and lifted to the sluice. As nearly as could be learned, while the capacity of this plant was from 15 to 20 per cent higher than the one previously described the work was not being done so cheaply. In the last case it was necessary to pump the seepage water from the pit, while in the first case all seepage water was naturally disposed of by draining into the peculiar cavernous limestone bed rock. In derricking plants in general, large rather than small buckets or skips are to be recommended, but the various elements of the plant should be so coordinated that the capacity of the derrick is not above that of the shoveling and tramming or of the sluice.

The derricking plant seen on Pedro Creek, in the Fairbanks district, has been described in connection with the method of using the cable

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tram and self-dumping bucket in open-cut work. Its efficiency was found to be high and its cost low in comparison with this well-known Klondike method. In general it may be said that derricking is a simple, efficient, adaptable, and comparatively cheap method of working open cuts where gravel must be shoveled into the first receptacle by hand and the bed rock cleaned by men.

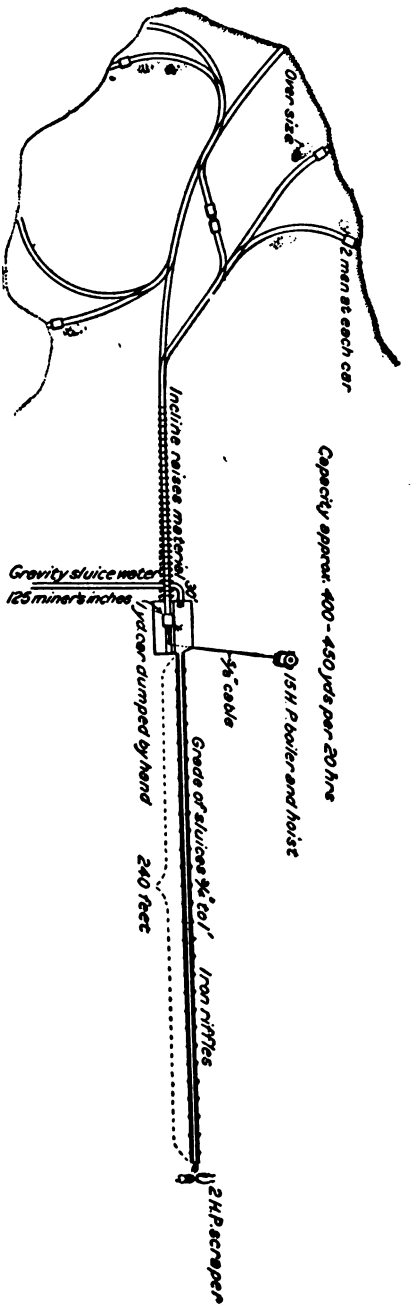



Fig. 9.—Plan of track-and-incline system, Anvil Creek.

### TRACKS AND INCLINES.

The track and incline working at No. 8, Anvil Creek, Nome district, is fairly representative of open-cut work by this system. (See fig. 9.) A special feature of the plant, however, is the removal of the overburden, in all 7 feet of muck and 5 feet of barren gravel, by hydraulicking. Seven hundred miner's inches are used through a giant, under a pressure of 200 feet obtained by pumping. After the barren ground has been removed the remaining gravel, averaging about 6 feet in depth, is shoveled into cars, pushed to the foot of an incline, elevated, and washed. The tailings are impounded on the claim, being scraped from the end of the sluices by 2-horse scrapers.

At the time of observation 6 cars were in use, though this number can be varied to suit the conditions in hand. Two men are employed with each car. They take turns in shoving the car to the incline, one remaining at the bank with pick. The cars at this plant were of a capacity of 22½ cubic feet, though larger ones might be found more economical. From 250 to 300 cars are run up each 10-hour shift.

The material is lifted 30 feet to the mud box and there dumped by

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hand. A man is continually employed for this duty. He also watches large bowlders and prevents jamming in the flume. However, very few large stones are allowed to pass through, for in the work of excavation the larger rocks are piled at one side of the track.

One man is employed at the hoisting winch and does his own firing. Three 114-pound sacks of coal are consumed each shift. A 15-horsepower boiler is used with vertical engine, and a five-eighths inch cable hauls the cars.

The dump box is 24 feet long, 4 feet wide, and 3 feet high, and has a grade of 1 inch to 1 foot. Following this are 240 feet of boxes with a grade of three-fourth inches to 1 foot. The boxes are 16 inches wide and 14 inches high, and are supplied with cast-iron grate riffles. These are 16 inches square and can be used either as Hungarian or longitudinal riffles. In washing, 125 miner's inches are used, all obtained by gravity from a claim above. After being used the water is caught in a retaining dam, settled, and carrried by flume to a lower claim, where it is sold. Two 2-horse scrapers are used to keep tailings clear, and all gravel is impounded by a brush dam upon the claim.

A little gold is caught in the entire string, though by far the greater proportion is retained in the mud box and that following. In the mud box a perforated iron sheet laid over the riffles aids the moving of material and prevents clogging. In the center of this sheet is placed a heavy iron plate which receives the heavy fall from the cars and saves the bottom of the mud box.

Bed rock on this claim is mica-schist, though in places the pay is underlain by a stiff clay. The gold sinks in the broken schist about 2 feet, but not at all in the clay.

A bed-rock drain, 250 feet long, has been cut nearly level, which is joined by small drains from various parts of the pit. Only about 15 miner's inches of water were running from the drain at the time of observation. Men are paid $5 a day, with board.

The advantages of the car-and-incline system are not especially pronounced. The method of stripping used in the above-described plant, or at any plant where water under pressure is available can hardly be improved upon. Where the overburden is thawed or where frost is encountered only in spots, as in the claim under discussion, hydraulicking has been found the most economical and efficient means of removing material. The car system, however, has little of solid economic advantage to recommend it. In order to increase capacity more men must be employed to shovel. In this system an undue proportion of time is consumed in tramming the cars to the top of the incline. A mechanical system, such as derricking or steam scraping, has many advantages over the track-and-incline. In the Klondike, so far as could be learned, the track-and-incline system does not make so economical a showing as other methods of working open cut, although the opportunity for comparison of efficiency was limited.

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## THE STEAM SHOVEL.

Where the ground exceeds 12 feet in depth and is unfrozen, certain conditions justify the installation of a mechanical excavator of large capacity, say 1,000 cubic yards or more in twenty-four hours. It will seldom be found advisable to install so large and so cumbersome a machine as the steam shovel in the creek diggings of Alaska, for the ground is rarely deep enough to justify the expense of installation. On bench diggings, however, where the pit can be drained by gravity, the steam shovel has a value which has probably been underestimated. The fact that water under pressure is difficult or impossible to obtain for the hydraulicking of benches raises the question whether these bench gravels can not be excavated by other means. The value of the steam shovel lies in the fact that it performs for the earth worker that portion of his work which would otherwise be most expensive.

The ground which the shovel is to move must possess certain favorable conditions. In the first place, it must be entirely free from permanent frost when the dipper lip of the excavator attacks it. If the ground holds a certain amount of permanent frost and this can be thawed by ground-sluicing the muck off at a period far enough ahead, the shovel may still have a profitable field, but its operations are likely to be more expensive. Heavy gravel and bowlders are easily handled by the mechanical excavator. It is safe to say that no quality or state of the Alaska gravels makes them unfit to be dug by the dipper except the frozen condition.

The bed rock must be of sufficient softness to allow the dipper lip to dig far enough into it to recover all the gold; otherwise a gang of men will have to follow the shovel to clean bed rock, and a large part of the value of the shovel will be lost. In one attempt to operate with a steam shovel in the interior of Alaska it was found that as many men had to be employed in cleaning the bed rock as in the entire remainder of the plant.

A prime essential to success, as has been proved by experience, is that the washing plant shall be isolated, the gravel being conveyed from the dipper to the sluice by some form of tramming. If cars are used, they should be large—2 yards capacity, or even larger. Under ideal conditions the dipper will dump into cars which run by gravity to the hopper of the washing plant, the water being brought to the sluice also by gravity. The full cars would in this case carry the empties back to the pit. It is rarely possible, however, to find an auriferous gravel deposit in which such eminently fit conditions exist for work. The tramming, even when it must be up an incline to a height of 35 feet above the pit floor, adds proportionately little to the expense, as will be seen by figures following. It is a common fault in all steam-shovel operations that the shovel is ahead of the car discharge.

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A partly idle steam shovel, however, is not so serious a fault as idle men, since the shovel draws no pay.

As to capacity, it is likely that a 2-yard shovel, fitted with extra long boom and 1¼-yard dipper, will be found most economical. A 25-foot bank can be dug and caved. If the sluice and tramming capacity is 700 cubic yards a day, the shovel will easily supply the material if no frost is encountered.

Pl. XI, *A*, shows one of the steam shovel plants in Alaska, operating on Anvil Creek. The work done by this shovel is considered satisfactory, though its installation is experimental, and a larger one is planned. It supplanted a hydraulic-elevator system which was condemned. The 25-ton shovel (three-fourths-yard dipper) is working on an 18-foot face. It has not reached the bottom of the gravel, and must make another cut 7 feet lower vertically before all the pay is extracted. It is said that from July 23 to September 1, 1904, 25,000 cars of 1¼ cubic yards capacity were dug and moved to the sluice boxes at a working cost of 12 cents a yard. The low bench is sufficiently above the level of the present creek to permit the pit to be

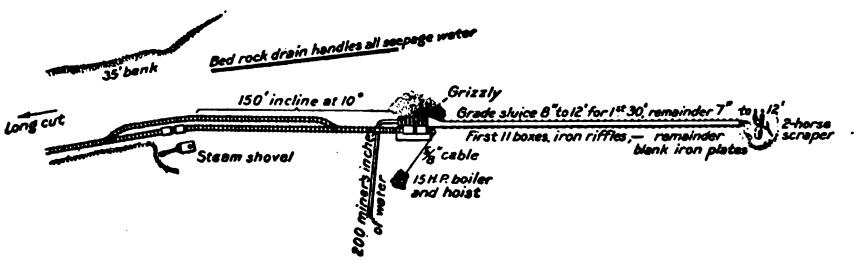



FIG. 10.—Plan of steam-shovel operations, Anvil Creek.

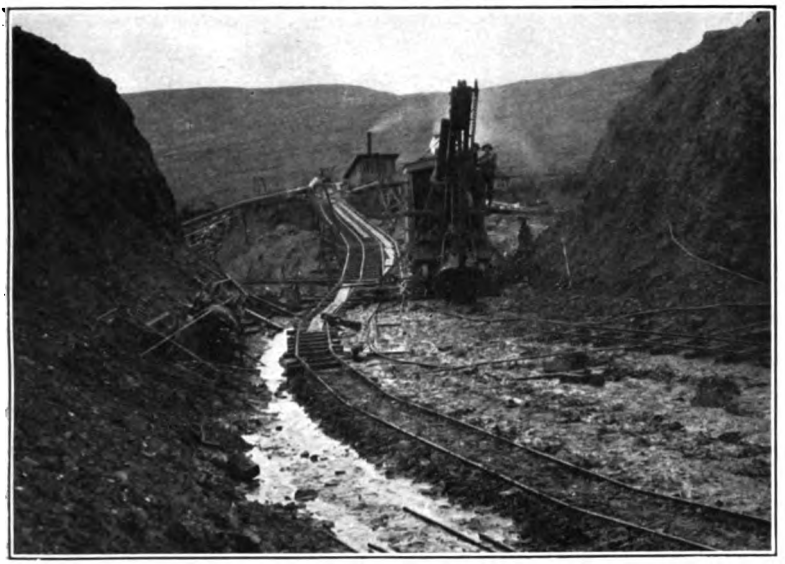
drained, the seepage water being handled by bed-rock drain. The workings were visited a second time three weeks after the present cut was made. A complete section of the bank to bed rock is given below:

| | Feet. |
|---|---|
| Muck | 3 |
| Fine gravel and sand | 5 |
| Fine subangular gravel | 5 |
| Large subangular schist and limestone fragments, stained with iron oxide, with a few bowlders up to 3 feet in diameter | 15 |

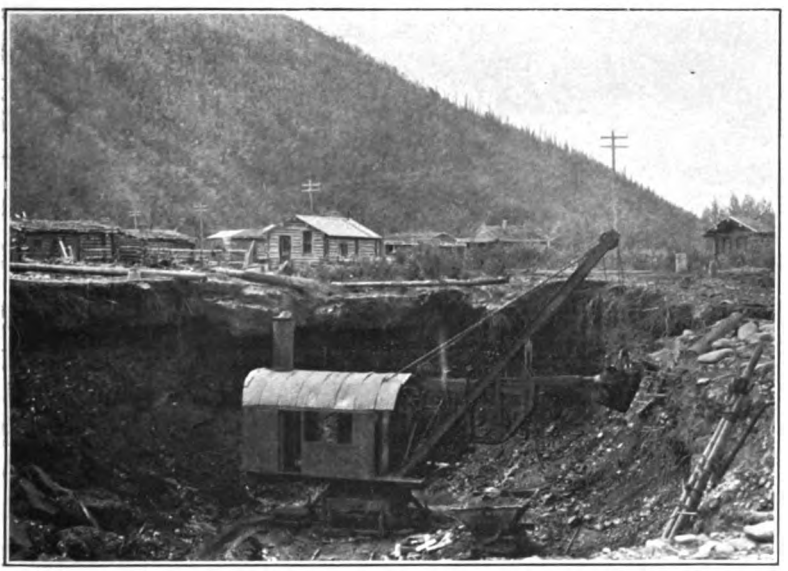
The upper 3 feet of muck was ground-sluiced; the remainder was moved by the steam shovel.

This frozen ground illustrates the peculiarly trying conditions with which the Alaska placer miner has frequently to deal. None of the ground encountered in 1904 was frozen. In the early part of the season of 1903, however, on account of the light snowfall during the preceding winter, the sides of a cut operated on were frozen to a depth of 8 feet and to a distance of 15 feet into the bank. This was annual

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*A.* STEAM SHOVEL, ANVIL CREEK.



*B.* STEAM SHOVEL, BEAR CREEK, KLONDIKE.

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and not permanent frost. Had the attempt been made to work the ground at that time with the shovel the operations would have been greatly delayed. In Pl. XI, *A*, one of the frequent defects of the steam-shovel system is apparent—the shovel idle and waiting for cars. In this plant, after the shovel had worked to a considerable distance from the bottom of the incline, the 1¼-yard cars, 3 in number, were trammed to the bottom of the incline by horses and hoisted to sluice by a 15-horsepower hoist. The tramming may be more cheaply accomplished, where there are several years' work ahead, by a small locomotive in the pit running to the bottom of the incline or, under favorable conditions, directly to the washing plant. Fig. 10 shows a plan of the operation under discussion.

The tramming system illustrated by fig. 11, used at Galesburg, Ill., in one of the shale pits of the Purington Paving Brick Company, is considered highly economical in steam-shovel work. As may be

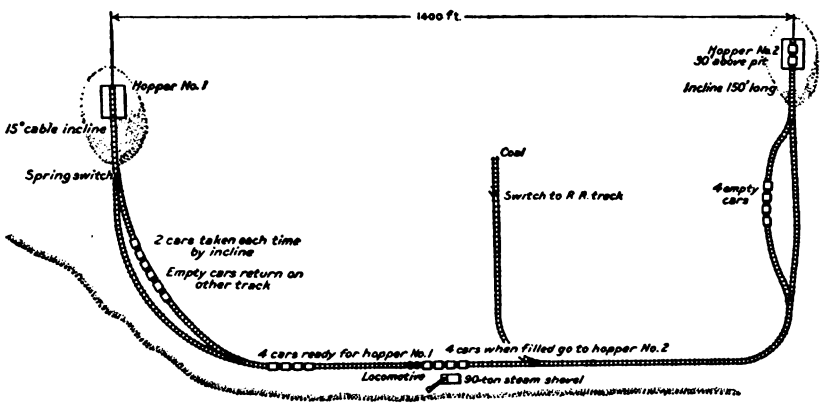



FIG. 11.—Plan of steam-shovel operations, Galesburg, Ill.

seen, the locomotive occupies a position intermediate between the two trains of cars, which deliver two ways to the bottom of two inclines leading to the hoppers of the clay machines at each end of the pit. In placer operations, if conditions admit of dividing the water to two washing plants, this system is to be recommended, as it allows of rapid delivery of the cars from the shovel. In this plant the locomotive keeps 20 cars going, each of 2 yards capacity, tramming them alternately, in trams of 6 and 4, two ways to the ends of the pit, whence they are hauled, two at a time, to the hoppers. When empty they run down and are switched automatically to the empty tracks. The 90-ton shovel, of 5-yard dipper capacity but fitted with 2-yard dipper, is ahead of the capacity of the clay machines, but must be used owing to the difficulty of digging the firm shale which composes the bank. The actual yardage moved, working nine hours a day, is 670, or at the rate of 1,488 yards in

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twenty hours. It is estimated that this is less than one-half the amount that could be handled were the shovel digging loose gravel. As it now works, the shovel is digging only one-third the time.

For moving up the cars within reach of the dipper as each one is filled the device shown in fig. 12 is used. This was devised by Mr. W. S. Purington, and has been in successful use at this plant for five years. The long cylinder, made with casting to attach to the shovel, here shown on the near side, contains a piston of equal length, which is supported on suspended track and wheel as it leaves the end of the cylinder. To the near end of the piston a cable passing over a sheave is attached. The other end of the cable is hooked to the corner of the gravel car, steam is turned into the near end of the cylinder, and

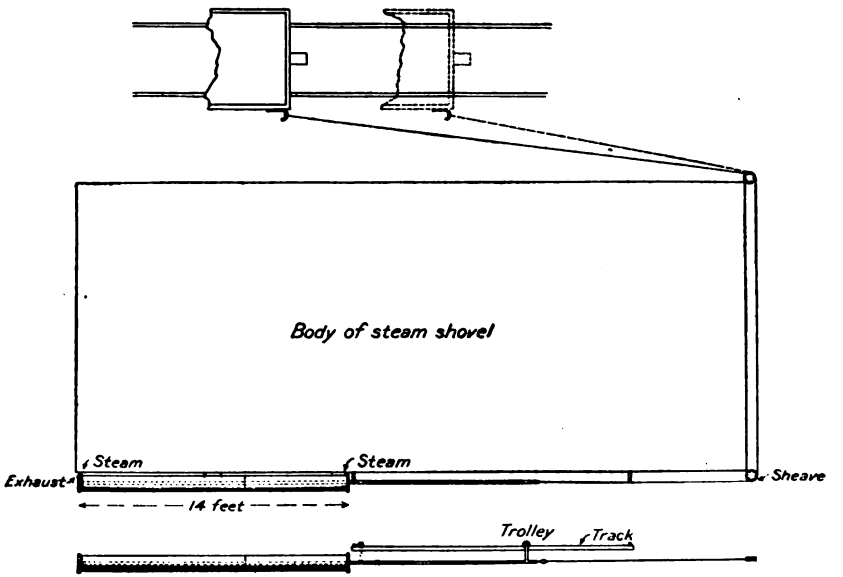



FIG. 12.—Pulling-up device for steam shovel.

as the piston travels back toward the forward end of the shovel car the gravel car is hauled by the cable an equal distance, from 5 to 7 feet, as may be required. Steam is then turned into the cylinder, allowing the piston to return and the cable to free itself; the cable is unhooked and pulled by the car man to the following car and hooked in readiness to pull it along. The amount of steam and the time consumed in the operation are so small as to be almost negligible. By passing the cable around the body of the shovel car over a second sheave the cars on the opposite side of the shovel can be moved, when the relative position of the shovel is reversed.

Dipper chains are generally preferable to cables in placer operations, as illustrated by the experience of the shovel dredge in Solomon

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River, elsewhere described. A link in a chain can be repaired where a wire cable can not.

The moving of the shovel as the digging progresses must be brought down to the most economical and rapid system possible. In the Galesburg operations wooden skids of 6-inch timber, 3 by 3 inches in dimensions, are hung from the jack frames by chains, and thus require no attention when the shovel is moved up. On these skids rest 6-inch blocks, 2 by 2 feet, on which the jack shoes bear.

In the Anvil Creek plant the present arrangement for dumping the cars at the sluice is unsatisfactory, and will be changed. Self-tripping two-way dumping cars will be substituted for the man who trips the cars. The sluice presents no new features. It is 500 feet long by 32 inches wide, by 36 inches high at the dump box, and narrows to 26 inches wide by 24 inches high, in 10-inch grade, and is furnished with angle iron riffles. The cost of digging, tramming, and dumping the gravel to sluice is said to be 12 cents per cubic yard.

The cost of steam-shovel operations in Alaska is not evident from the cost sheet (table 1, p. 38), as the figures there given cover the sluicing, often with purchased water, stripping, amortization, etc. In the Anvil Creek operation the actual working cost of digging the gravel, tramming and hoisting, and tripping the cars to the sluice box is given below, as estimated by the superintendent, the figures covering 810 yards in twenty-four hours, and including superintendence on the ground, labor, crude oil fuel at $3 a barrel, lubricants, etc.

*Cost of steam-shovel work at Anvil Creek, Alaska, per cubic yard.*

| | |
|---|---|
| Digging | $0.045 |
| Tramming to incline | .025 |
| Hoisting | .018 |
| Dumping | .011 |
| Proportionate superintendence on ground, and incidentals | .021 |
| Cost per cubic yard | .120 |

Figures showing the cost at the Galesburg plant, above referred to, are available in detail, for handling 17,422 cubic yards of shale per month of 26 nine-hour days, digging from 50-foot bank with a shovel fitted with 2-yard dipper, delivering to 20 two-yard cars trammed 2 ways, 1,500 and 2,000 feet, respectively, to bottom of 2 inclines, hoisted by cable to hoppers at elevation of 20 feet above the track and dumped to hoppers.

*Cost per month of steam-shovel work at Galesburg, Ill.*

| | |
|---|---|
| 1 engineer, shovel | $110.00 |
| 1 crane man | 85.00 |
| 1 fireman, at 22½ cents per hour | 52.65 |
| 3 trackmen, 17½ cents per hour (shovel) | 128.85 |
| 1 locomotive engineer | 80.00 |

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*Cost per month of steam-shovel work at Galesburg, Ill.*—Continued.

| | |
|---|---|
| 1 switchman, at 20 cents per hour | $46.80 |
| 2 hoist men, at 20 cents per hour (hoist men dump the cars) | 93.60 |
| 1½ tons coal for shovel, at $2 | 78.00 |
| ½ ton coal for locomotive | 26.00 |
| 1 ton coal for 2 hoists | 52.00 |
| Total | 752.90 |
| Cost per cubic yard | .0432 |

Charges for superintendence, oil, waste, and incidentals are omitted from the above. Including these the cost is practically 5 cents a yard. The comparison below, however, is based on the figure of $0.0432.

If two of the trackmen be charged to the shovel, the digging operation and transfer from bank to car costs $0.0236, or 54.6 per cent of the operation considered. In other words, the digging here costs little more than the long tram, hoisting, and dumping, and thus the object of using mechanical appliances is attained. A striking comparison is afforded by the cost of operating a placer which uses the car-and-incline system and the labor of men to fill the cars. If the duty of a man shoveling gravel into a car is taken at 12 cubic yards in nine hours, and the men are paid the lowest wage given in the above tables, namely $42.85 per month, 56 men, say, would be employed filling the cars, and the monthly cost would be $2,305, or $0.132 per cubic yard, 5.6 times as great as that with the shovel, or 84.8 per cent of the entire operation considered. In Alaska where wages for shovelers are from four to six times as great, the percentage of cost would be much greater.

Although the cost of 12 cents on Anvil Creek appears attractively low, it must be remembered that it does not take into account the labor of shovelers cleaning bed rock after the shovel. This operation, unfortunately, can rarely be dispensed with, at least in portions of the ground, and it will naturally increase the cost of getting the auriferous material into the cars. In some places in Alaska the slabs and leaves of bed rock must be scraped with brooms in order to recover all the gold. The prospective steam-shovel miner should keep in mind the fact that a machine which will handle a large quantity of material, however cheaply, is of no avail unless it can succeed in extracting a large percentage of the values.

The steam-shovel plant at the junction of Bear Creek and Klondike River occupies the flood plain of the latter stream, a fact that influences greatly the economical excavation and disposal of material, since both lack of grade for washing gravel and dump for disposal of tailings must be supplied artificially.

This steam shovel (see Pl. XI, *B*) digs in a pit 20 feet below the surface of the flat. The dipper empties into cars which are pushed by hand to the foot of an incline and raised by steam winch to the plat-

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form of the washing frame, where they are dumped by hand into a hopper. The material passes through a trommel, and the oversize falls into a self-dumping carrier and is elevated to dump. The undersize passes over tables and through sluices, and the fines are also raised by steam, a scraper being employed to secure dumping ground. There are, therefore, four distinct elevations, viz, by the shovel, the gravel by the tram, the coarse tailings by the bucket, and the fines by the steam scraper.

The pit in which the shovel works varies in depth from 20 to 24 feet. The gravel lies beneath 3 feet of muck, is generally mixed with considerable sand, and extends to bed rock. The material is well rounded and contains very few stones (but 1 per cent) that are over 18 inches in diameter. Considerable black sand is found in the clean-up. In spots the ground is frozen, necessitating the occasional use of steam points. Steam is conveyed across the cut in a covered steam pipe hung from a stretched cable. A schist bed rock, generally hard, is excavated for about 2 feet by the shovel.

The shovel weighs 35 tons and revolves 360° upon a turntable. The dipper holds 1 cubic yard, and the machine has a capacity of 1,000 yards in ten hours, though this can not be obtained owing to inadequate tramming facilities. Its cost on the ground is about double that charged by the manufacturer. The boom, when horizontal, reaches 22 feet beyond the bow, but when at level of track only about 14 feet. Three-quarter-inch cables are used in transmitting power. The faults of cables in steam-shovel practice in inaccessible localities have been commented on above. The dipper contains no new features. Prongs are added to save lip, the central one being longer than those adjacent. The machine has 3 engines and uses in all about 40 horsepower.

For conveying material three cars of 2 yards capacity each are used, running on a 3-foot gage track with 16-pound rails. The cars are pushed by hand to the foot of an incline, which has an angle of 22° and extends 100 feet, and thence elevated by cable connected to a 40-horsepower hoist. Two hundred and fifty cars are usually raised in ten hours. On reaching the platform the cars are dumped by hand and returned by gravity to the foot of the incline.

From the hopper into which the cars dump the gravel is fed into a revolving trommel 16 feet long and 3 feet in diameter supplied with a worm upon the inner surface and punched with holes varying from one-half to 1½ inches in size. The rate of feed is regulated by hand, a gate being raised and lowered when necessary. Water is supplied to the trommel by a 6-inch longitudinal pipe. All oversize passes directly over a sheet-iron chute into a square hopper, from which it falls by gravity into a self-dumping carrier and is elevated approximately 40 feet upon a dump. A 10-horsepower winch does this duty. The hopper is furnished with a heavy iron gate, raised by the steam

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winch running the self-dumping carrier, and is lowered by its own weight. The fines (the material passing through the trommel) fall directly on gold-saving tables similar in design to those used on many gold dredges. These tables (see Pl. XII, *A*), which are fed by two 4-inch pipes, are six in number (three on each side of the trommel) and have a gold-saving surface of 80 square feet. They are fitted with expanded metal and cocoa-matting riffles, which prove to be very efficient, the greater part of the gold being caught near the upper end of the first table. (See Pl. XII, *B*.) The material then passes to a longitudinal sluice which consists of eight boxes 22 inches wide furnished with Hungarian riffles constructed of 1- by 3-inch inclined cleats capped with three-sixteenths-inch iron. The tailings are removed by a steam scraper and elevated upon a dump. The winch for the scraper is 30 horsepower and elevates 400 4-wheelbarrow units 15 feet in ten hours, seven-eighths-inch cable being used. It will be seen that the above double elevation of material must be costly, using, as it does, not only much power, but also additional men on separate winches.

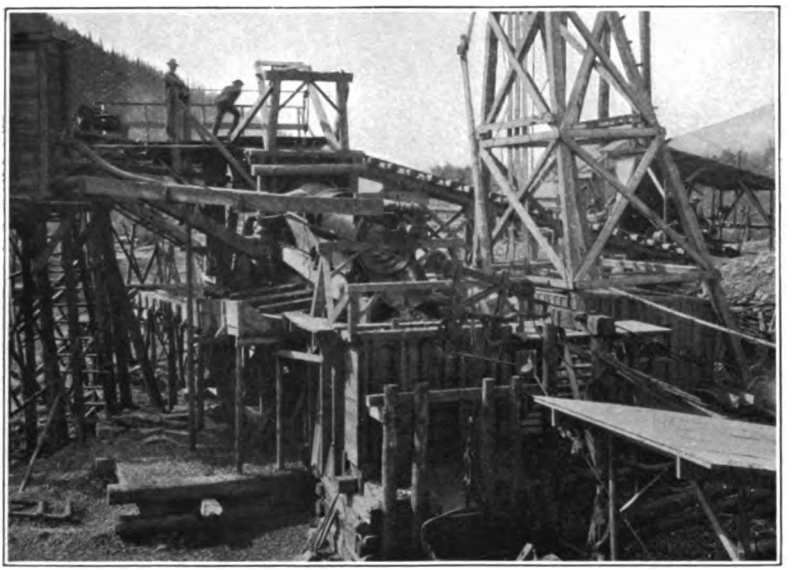
The greater part of the water for sluicing, 300 inches, is brought by flume from Bear Creek. The remainder, amounting to 100 inches, is raised from the pit by a series of pumps. A No. 6 centrifugal pump raises the water to the foot of the washing apparatus, from which it is lifted 25 feet by a No. 8 centrifugal and used for sluicing. A 35-horsepower engine does the latter work. An additional pulsometer pump is occasionally used in the pit.

The power plant contains two 60-horsepower boilers and one 50-horsepower boiler, wood being used for fuel. Sixty men are employed about the plant, the daily wage of the laborer being $4 and board. The men work two 10-hour shifts throughout the working season.

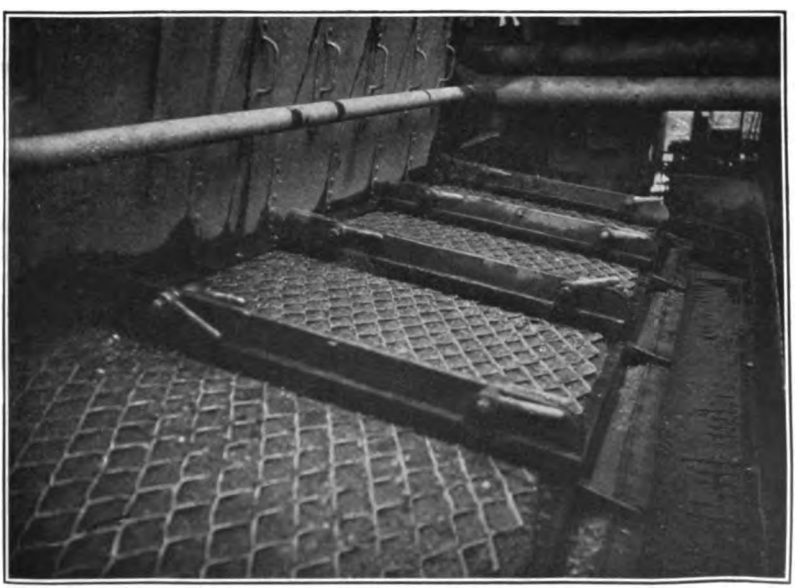
The above-described plant will undergo considerable change in the near future, improvements designed to effect greater economy being contemplated. It is planned to haul all material excavated a distance of 2,000 feet by locomotive, in trains of 6 cars, to a washing plant on the banks of Klondike River, where the ground is 8 feet below the upper edge of the pit, and then wash it by gravity water from Bear Creek. High water in the Klondike will greatly economize the handling of tailings, and it is hoped the full capacity of the shovel may be utilized.

A machine run on principles radically different from those described above is illustrated by a steam shovel on Eldorado Creek, in the Klondike region. In this case the use of a tramming system is entirely avoided by so arranging the plant as to allow direct dumping by the dipper into the sluice boxes. In this case the shallowness of the ground and the use of a 50-foot boom permit such an arrangement. The work lies in the creek bed proper and cuts are made longitudi-

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*A*. STATIONARY WASHING PLANT, KLONDIKE.



*B*. COCOA MATTING AND EXPANDED METAL RIFFLE.

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nally along the stream, the sluice boxes being moved every three or four days, following the progress of the shovel. This practice alone involves both good and bad features. The practice of dumping directly into the sluice is, theoretically, much to be desired, embodying, as it does, only one elevation of the gravel, an arrangement which consumes the least power and time—two all-important factors. The moving of the sluice boxes, however, in this case consumes much time—from one to two days for each move—and, wages being $6 a day and the season very short, constitutes a serious drawback, greatly reducing the capacity of the plant. The boom of the machine, as stated, is 50 feet long and hoists the gravels 30 feet above the cut. If an arrangement facilitating the moving of the boxes could be devised, so as to avoid the long delays caused by this operation, a very satisfactory result might be effected. Such a system requires a relatively shallow bank, however, and it is doubtful whether it is available for steam-shovel operations in general.

In this instance the gravel to be taken out is frozen, and continuous thawing must accompany the advancing work. In this work 15 steam points are driven into the bank to bed rock, where they remain twenty-four hours, the process consuming during that time 3 cords of wood. A 25-horsepower boiler is used for this duty. (See Pl. XIII, *B*.)

Water is very scarce at this plant and is used repeatedly, being raised from the pit by a centrifugal pump and carried back to the sluice boxes in a flume. The pump also serves to drain the pit. The sluice boxes have a grade of 9 inches to 12 feet, but, with the water at hand, are unable to keep pace with the capacity of the machine.

The shovel carries a one-yard dipper operated by chains. It is claimed that 1 cubic yard is moved every two minutes. Bed rock of a slaty nature is taken up to a depth varying from 2 to 5 feet.

The problem of disposal of tailings is a difficult one and has not been solved economically. A steam scraper is used and all tailings must be scraped to one side and elevated. Not only is the expenditure for wood an item, but a man must be constantly attending the scraper while another handles the steam winch.

A tramming system which would convey the material to be washed to such a point as would admit of the disposal of tailings by gravity, even if a thousand feet or more distant, would be a more economical arrangement, saving, as it would, not only all elevation of tailings, but also all delay in moving the washing apparatus.

Ten men are employed about the plant each shift, occupied in scraping tailings, forking gravel in dump box, running shovel, attending steam points, and in cleaning bed rock at places where the dipper could not effectually work.



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The shovel is moved by rollers running on skids, power being obtained from the shovel winch. The dipper is furnished with soft steel prongs which wear very rapidly.

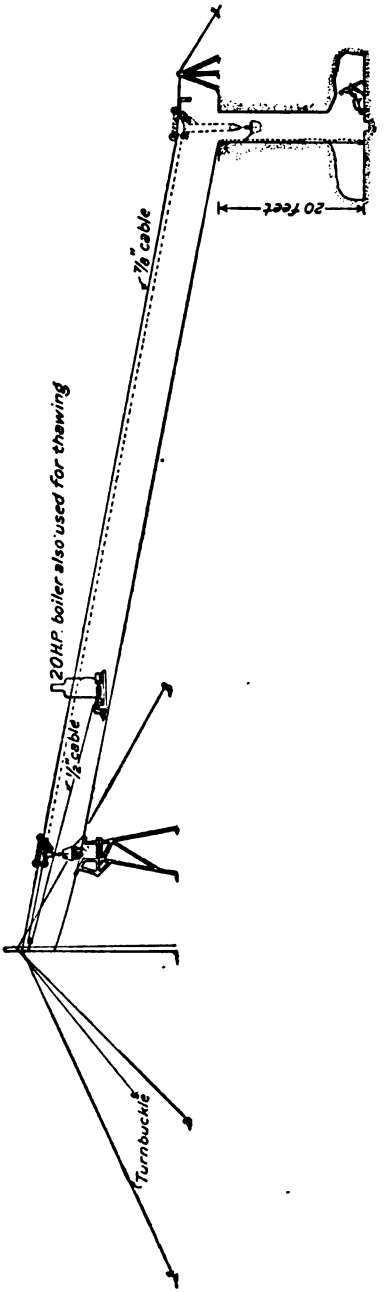



FIG. 13.—Rig for small drifting operation.

## DRIFT MINING.

### INTRODUCTION.

Northern gold-gravel deposits, that are sufficiently rich to warrant the method, can generally be exploited by drifting beneath the overburden at all times of the year. In drift mining creek deposits the gravel is hoisted through shafts, and where bench gravels are worked it is generally trammed through adits. In all portions of the interior of Alaska and in the Klondike the drifting of auriferous gravels has been carried on with fully as much activity in the winter as in the summer. As may be seen by the cost sheet, the expense of winning the gold by winter drifting and spring thawing is greater by over $1 per cubic yard than that of summer work. This increase is due to the necessity of rehauling and, in many cases, of rethawing the dumps in the separate process of sluicing. In consequence, only the richer ground, running from $6 to $10 to the cubic yard, can be profitably drifted. The price of labor during the winter in the interior is only 25 per cent less than in summer, so that this does not afford a great offset to the increase of cost from other causes. In Seward Peninsula, where the price for winter labor is only $2.50 a day and board, as against $5 in summer, it would seem that winter drifting can be undertaken more generally than heretofore. A reliable operator of Nome is of the opinion that

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winter drifting operations should be continued in that vicinity where timbering is necessary but thawing is not, and where the gravel can be trammed to surface through adit for $3 per cubic yard, including all expenses of extraction and sluicing-up in the spring. This is less than double the cost of drift mining in the Forest Hill divide region of California, where conditions are eminently favorable.

Neglect to sample is the worst possible practice, as many lamentable failures have resulted from overconfidence in the value of the ground taken out, and the miner who confidently waits for the big wash-up before thoroughly knowing the amount of gold in the material he is handling is frequently doomed to disappointment. The method of sampling the dump, given under the heading "Hydraulic mining" (p. 118), is to be highly recommended for all work of this nature.

Where timber is scarce and costly, and wood for fuel has to be hauled from a distance, it is advisable to consider the entire abandon-

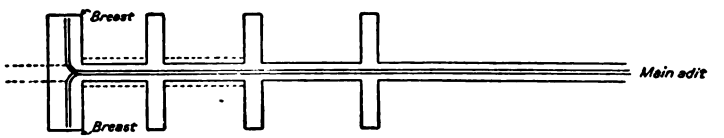



FIG. 14.—System of opening drift mine.

ment of attempts at winter work. The amount of gravel which can be hauled is less, and the cost per cubic yard is greater. The time spent in sluicing the winter dump may frequently be more profitably employed in preparing for the summer. The ordinary small rig for drifting operations without timbering is shown in fig. 13.

## DRIFTING AND TIMBERING.

Drift mining, whether the workings are approached by shaft or adit, can be most economically conducted by adopting the system which proved so successful in California. The mine is opened by a main tunnel or runway, 6 by 6 feet, which generally requires timbering, with logs 8 by 8 inches, 6 feet long, the sets having 5-foot centers. This runway is continued out to the end of the block of ground which it is proposed to work, say from 50 to 100 feet in ordinary Alaska operations. It is assumed that the runway occupies the longer dimension of the ground and approximately the center of the pay streak, say 75 or 100 feet in width. From the main tunnel drifts are run transversely each way to the outer edges of the pay. These generally do not require timbering in frozen ground. Fig. 14 illustrates the system of main runway and drifts. The gravel can now be breasted out, a face being carried the full width of the pay and the work being continued in two or more of the drifts, as desired, the breasts being always carried toward the shaft or adit mouth. The drifts may be

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timbered either with sets, where ground is heavy, with single posts and caps in moderately firm ground, or left entirely untimbered, as in solidly frozen ground. Fig. 15 shows the manner of timbering closely and rock filling behind when breasting out faces of loose gravel in the Hidden Treasure gravel mine in California. The sketch is made up in part from report of Mr. Ross E. Browne,[a] and in part from the writer's own observations. The system of filling behind with quartz stones is impracticable for Alaska mining; instead of this timbers should be pulled and the ground allowed to cave. This form of timbering is in use in the drift mines of Solomon Hill, Klondike, except that instead of separate base blocks sills are used. Fig. 16 shows a portion of the drift operations which were prosecuted on Solomon Hill in the early years of the Klondike exploitation. The plan of the workings is here reproduced by courtesy of Mr. George T. Coffey, manager of the Anglo-Klondike Mining Company's

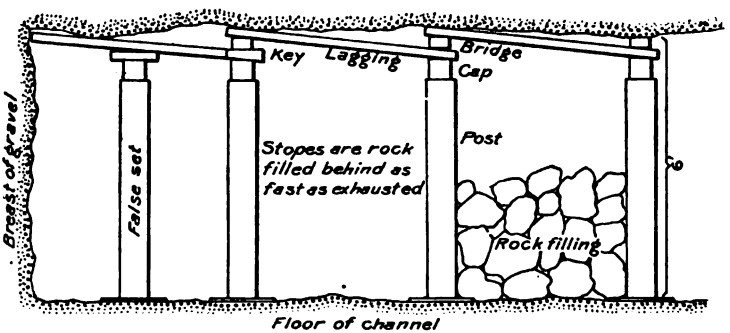



FIG. 15.—Hidden Treasure system of timbering drift mine.

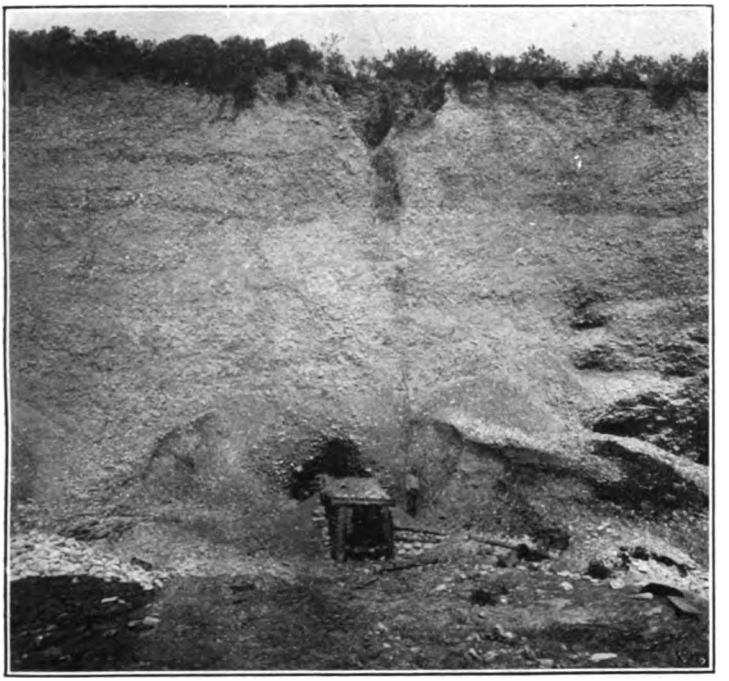
operations. The drifting operations in the southern portion of the ground are still in progress. Pl. XIII, *B*, shows the mouth of one of the adits leading to the operations.

The main adits are timbered with 4-inch timbers, in sets with 5½-foot centers, at a cost of $1.75 for framing and putting in per foot of tunnel run. The entire cost of driving the tunnel 5½ feet high, including steam thawing, excavating, tramming, timbering, and laying track of 12-pound rail, was $6.25 per foot. Transverse drifts were run from the main adits, and the ground was always breasted out in the direction of the adit mouth. The irregularity of the workings in a portion of the ground is accounted for by the fact that a certain amount of unsystematic work had been done previous to the purchase of the ground by the present company.

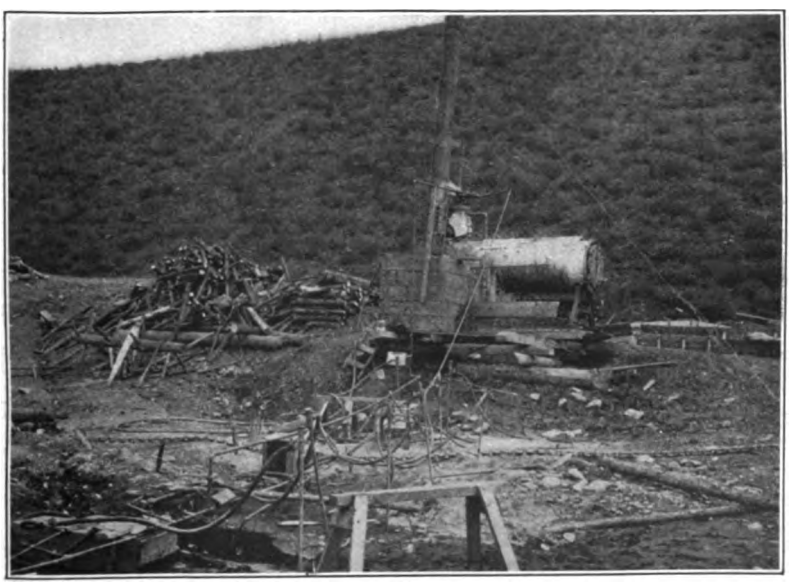
The ground is solidly frozen and had to be thawed by steam points. The rate of speed with which the work was carried on may be judged from the fact that two men, working a shift in running a straight

[a] The ancient river beds of the Forest Hill divide: Tenth Ann. Rept. State Min. Cal., 1890, p. 452.

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A. ADIT TO DRIFTING OPERATIONS.



B. THAWING AHEAD OF SHOVEL, ELDORADO CREEK.

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tunnel after the points had been left in fourteen hours, averaged 5½ feet, including taking out the points, putting in timbers, keeping up the track, and driving in other points to a distance of 5 feet. The average height to which the gravel was taken out in a representative block was 4 feet. Pl. XIV, *A* (p. 86), shows the remnants of old drift timbers in ground which has been hydraulicked subsequently to the drifting of the rich bed-rock pay. The cost of mining was $5.50 per

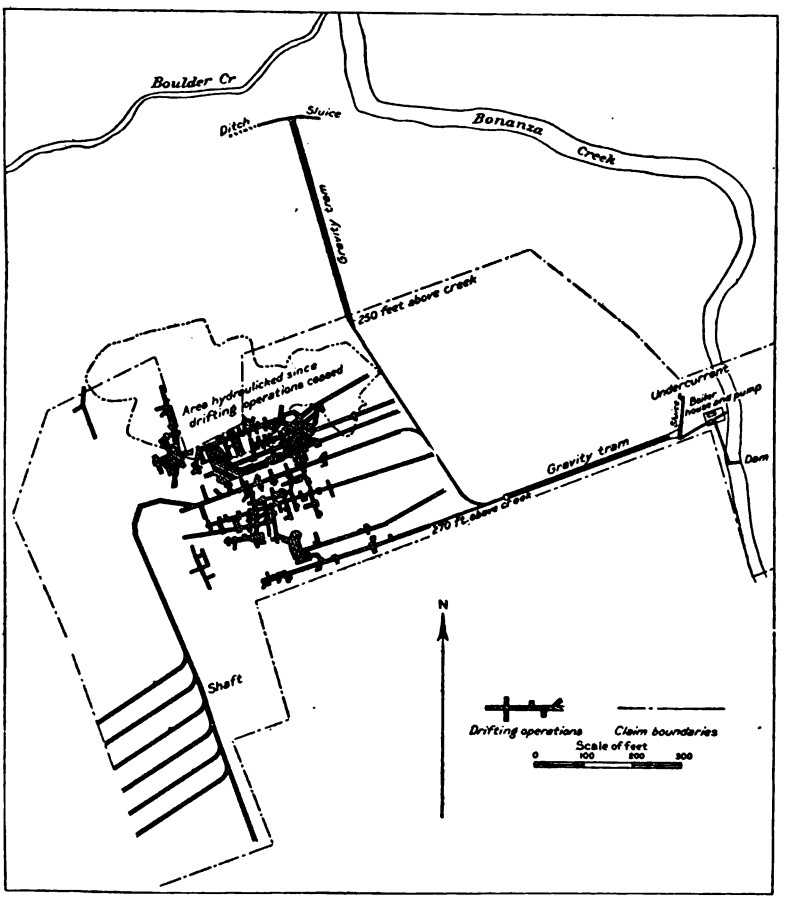



FIG. 16.—Plan of drifting operations on Solomon Hill, Klondike.

square yard of area worked. In drifting out the ground it was found that three points in a face 6 feet wide, allowed to thaw twelve hours and then withdrawn, the ground being "sweated" twelve hours longer, would thaw all the ground. The sluicing was conducted in the ordinary way of piling up the dump and afterwards caving and hydraulicking with a nozzle into the boxes. The actual working cost of washing was about 18 cents per square yard of area worked.

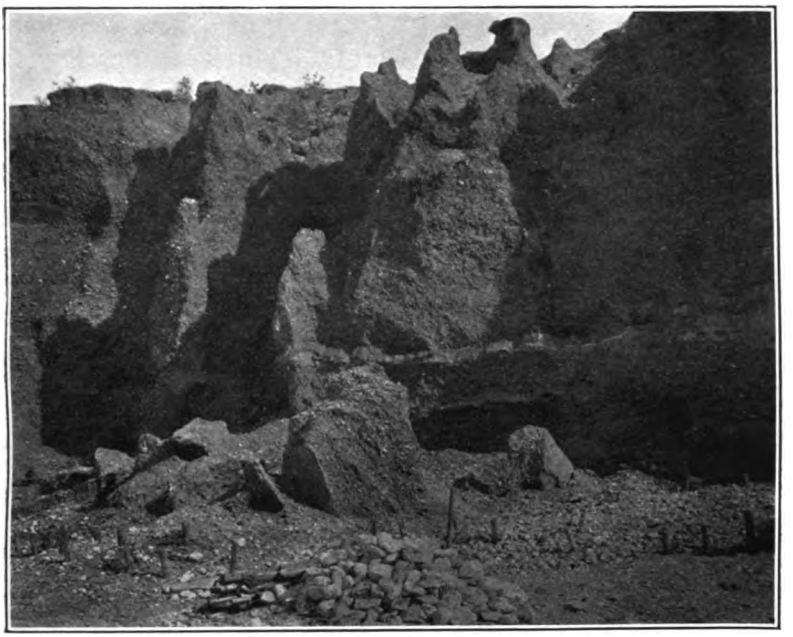
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In drifting operations on a bench of Anvil Creek, Seward Peninsula, a main long adit was run 4 by 6 feet 6 inches in the clear, at a cost of $4 a foot, untimbered, for the entire width of the ground in a direction transverse to that of the creek. This was 500 feet in length and was 10 feet below the surface of the schist bed rock. The average depth of the ground was 20 feet, being 2 feet of muck, 11 feet of wash gravel containing almost no gold, and 7 feet of pay dirt, the last consisting of 5 feet of pay gravel and 2 feet of bed rock, which contained the best pay. This was the thickness drifted. The adit served as a drain for the workings. The ground was only partially frozen, and it is likely, as has been found in parts of the Alaska interior, that the constant draining of the ground assisted in a gradual thawing of the frozen parts. From the end of this main adit, a long tunnel (600 feet) was run for the length of the ground which was to be drifted, at a level of 8 feet above that of the adit floor. This was timbered with 6- by 6-inch posts, 8- by 8-inch caps, sets with 4-foot centers, lagged with 2- by 6-inch plank, top and sides. From this long drift cross drifts were run in a direction parallel to that of the main adit, at intervals of 100 feet, and with lengths of 40 feet on each side of the main longitudinal drift. The ground was then breasted, carrying a 40-foot face toward the adit. The Hidden Treasure system of timbering, using false sets, was employed. Track was laid both in the main adit and in the upper workings, and cars of 21 cubic feet capacity were employed in tramming, 4 in the main adit and from 15 to 20 in the upper workings. The stopes never exceeded 20 feet in back and forward dimensions. The timbers used were 8- by 8-inch posts, 7 feet long; 10- by 10-inch caps, 11 feet long; 5-foot centers, all ways, between posts. Boards were laid down to shovel on. The ground was so heavy it was found impossible to save the timbers, but the track was all recovered. In extracting 21,000 cubic yards, timbering cost $14,000, with lumber at $50 per thousand.

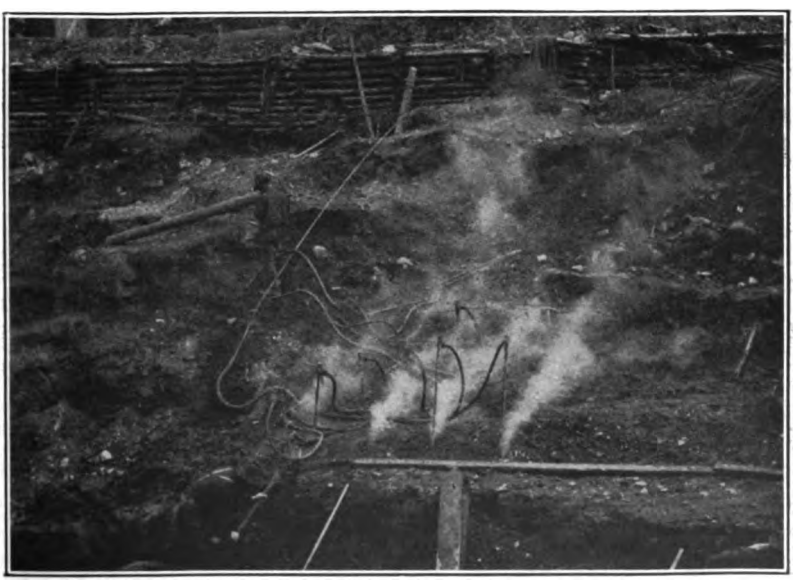
The gravel was trammed to surface and distributed on a long dump 40 feet on each side of a previously constructed 24-inch sluice 500 feet long. As usual, planks were laid on top of the sluice, and when spring opened the gravel was caved and horse scraped into the sluice. In distributing the gravel on the dump 3 men and a horse scraper had to be employed most of the time in keeping the snow off, on account of especially heavy snowfalls when the work was being done. When completed, the dump measured 700 by 80 by 20 feet, approximately. The drifting work consumed nearly eleven months, and the sluicing about two months, being delayed on account of frost in the gravel.

Labor employed averaged 45 men in two shifts of ten hours, at winter wage of $2.50 a day and board. A shift in the drifting operations consisted of 10 men shoveling into cars, averaging 8 cubic yards to the man; 3 to 4 trammers took care of the dirt shoveled. In sluic-

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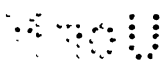


*A.* OLD DRIFT TIMBERS IN HYDRAULIC PIT, KLONDIKE.



*B.* APPLICATION OF STEAM POINT IN OPEN-CUT WORK.

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ing, 10 men and two 2-horse scrapers were used to a shift. The product of the operations was $160,000; and the cost, including preliminary prospecting, was 59 per cent of the output. The work was done in 1901–2, and the opinion was given by the operator that the cost could be decreased 20 per cent under present conditions.

In drifting operations on high benches lying between Anvil and Dexter creeks near Nome the gravel must be hoisted through shafts. It is said that powder is efficient in extracting the frozen ground. This is contrary to experience in the Alaska interior, and is doubtless due to the fact that the gravel is not nearly so solidly frozen. In fact, it is said that the powder is used for only a portion of the time. From the main shaft, which must be in some cases 230 feet deep to reach the second pay streak, a drift is run the length of the pay ground. From this, transverse drifts are run at alternate intervals of 50 feet in each side of the main drift. Some operators sink the shaft on the side rather than in the center of the ancient channel, as by this method the shaft is less likely to "squeeze." The shafts are 3 by 6 feet, timbered with 2- by 12-inch plank laid up on the sides, with 2- by 4-inch timbers set vertically on the corners inside.

The face can be carried from 50 to 100 feet in length in the winter, as the constant slight freezing renders the gravel less heavy. In summer, on the other hand, the ground must be worked in small blocks. With the methods of timbering in use, 6- by 6- to 10- by 10-inch sawed posts are put in, on base block, and with a short 4- by 12-inch plank cap, posts having 3-foot centers in all directions. A space of 3 sets in width is generally carried before the ground is allowed to cave. When the ground is ready to cave a bulkhead is nailed to the second set, the timbers are pulled with ropes from the third, and the caved ground is caught by the bulkhead. The breast is then carried forward as before. No lagging is used except in the shaft and the main runway. In summer work the area of bed rock exposed in one stope rarely exceeds 10 feet square.

In sluicing the dumps from winter operations on the high Anvil benches, the expedient is adopted of building small dams of sod and erecting snow fences behind them to catch snowdrifts, so that sluicing water may be afforded in the spring from the melting snow. The remarkable phenomenon of deep-lying pay streaks on the Anvil benches has been considered by Mr. A. J. Collier[a] in his geological account of the Nome district.

On Eagle Creek, in the Birch Creek district, an interesting drifting operation was seen. It is especially difficult to work the creek claims by drifting on account of the partially thawed character of the gravel. A bed-rock drain was run in winter at one side of and parallel with the

[a] The placer deposits of Seward Peninsula: Bull. U. S. Geol. Survey, in preparation.

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pay streak, and low enough to drain all the ground which it was proposed to work. The drain was covered and lagged with poles and thus rendered permanent. A shaft was then sunk at the lower end of the ground, 4 by 8 feet in dimensions and 20 feet deep. This was timbered only for the upper 14 feet, and was sunk in three days by 2 men. A tunnel was then run upstream the length of the ground, wide enough to admit 8-foot caps. Posts were 5 feet long, all timber being 9 inches square. Sets had 4½-foot centers, and the tunnel was lagged overhead with 2¼-inch flattened poles. A set of timbers delivered cost $4, there being 34 caps to a cord of wood. Lateral drifts 8 feet wide were driven at intervals of 8 feet, 4½ feet in thickness of gravel being taken. The gravel was wheeled to the shaft and windlassed to surface, about 25 cubic yards being raised in ten hours. The lamentable lack of any tramming arrangement for transporting the gravel to a distance resulted occasionally in the caving in of the ground from the added weight of the dump. The gravel so laboriously raised was thus lost. Some idea of the difficulties of operating on Eagle Creek may be seen from the following figures: Wood was $10 a cord, not excessively high; lumber, $180 a thousand; and freight-packing rates from Circle on the Yukon, 25 cents a pound in summer and 8 cents in winter. Considering the remoteness of the district, the work carried on was remarkably good and systematic.

## THAWING.

One who has never visited the interior of Alaska finds it difficult to conceive the formidable condition of solidly and perpetually frozen alluvium which is there encountered by the placer miner. The quantity of water in the form of ice which occurs in the frozen gravel averages about 25 per cent; while in the overlying fine, black silt which forms the overburden the quantity of ice varies from 50 to 75 per cent. Whatever may be the physical composition of the material, it forms a mass as solid and as difficult to penetrate as solid stone, and can be disintegrated only by exposure to the sun's rays or by the long-continued application of some form of energy artificially applied.

In any open-cut operations the dense blanket of moss, from 12 to 18 inches in thickness, which covers the frozen ground, must be broken into and turned over either by adzes or plows before the action of sun and water can take any effect on the underlying muck. As has been said, this effect is remarkably rapid when the water is allowed to run over the exposed black and icy mass.

A curious condition exists in the treeless areas of Seward Peninsula. Wherever a growth of stunted willows occurs, the ground beneath is found to be thawed, and wherever the willows are replaced by moss the ground is frozen solid. The rule is not without exceptions, but has been found to have rather general application. The distribution

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of the willows and moss-covered patches in the creek bottoms and along the low valleys appears to be entirely irregular. For further notes on the frozen and half-frozen conditions existing in the interior reference may be made to the matter presented under the heading, "Prospecting."

Drifting operations in the creek deposits of the Klondike, Birch Creek, Fortymile, and Fairbanks districts of the interior are nearly always carried on in solidly and perpetually frozen ground. A necessary accompaniment of the work is the thawing of the ground by artificial means. Mr. Greenleaf W. Pichard has thoroughly investigated for this report the possibilities of using any form of the electric furnace for thawing the frozen gravel, and has reached the conclusion that electric thawing is impracticable. The thawing of ground which lies open to the air, by the combined agencies of sun and water, will be considered under the heading "Hydraulic mining." Artificial power, through the agency of the steam point, is only in rare cases applied in open-cut work. The Klondike district afforded a few examples of this application of power, notably in connection with dredging operations on Bonanza Creek, the steam-shovel operations on Bear Creek, and in two open cuts on Upper Dominion and Hunker creeks. Pl. XIV, *B* (p. 86), shows an application of the steam point to open-cut mining on Hunker Creek. It is difficult to determine the efficiency in open work, as, naturally, a portion of the thawing is done by the sun. From the data collected, however, it does not appear to be any greater than its underground efficiency, which will be presently discussed.

The method of thawing gravel underground by wood fires is expensive and, unless the conditions are very exceptional, is not used in those districts where transportation facilities permit the bringing in of boilers.

According to experience on Deadwood Creek, Birch Creek district, the efficiency of a wood fire in creek ground was as follows: A fire taking three-fifths cord of wood (at $12 a cord) is built against the face of the bank. The pile of wood will be 18 inches wide, 2 feet high, and 25 feet long. Stones are laid up over the pile and a space is left to light the fire. The fire is lighted at 5 p. m. and left to burn until 8 a. m. the next day. The stones, which quickly get hot, are regarded as most efficient in thawing. On a 4-foot thickness of pay this amount of fire will thaw, in the time specified, from 5 to 6 cubic yards of gravel. This is at the rate of 9.2 cubic yards thawed to the cord of wood, which is considerably less efficient than the method of thawing with steam. Time, delays, and awkwardness of the method, moreover, make wood-fire thawing the most expensive that can be adopted. The figures per foot for shaft sinking range from $3.16 to $7.50 in taking gravel from prospect shafts. The efficiency given in

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the above-cited case on Deadwood Creek appears to be very nearly the same as that given by Mr. E. D. Levat[a] for the operations in eastern Siberia.

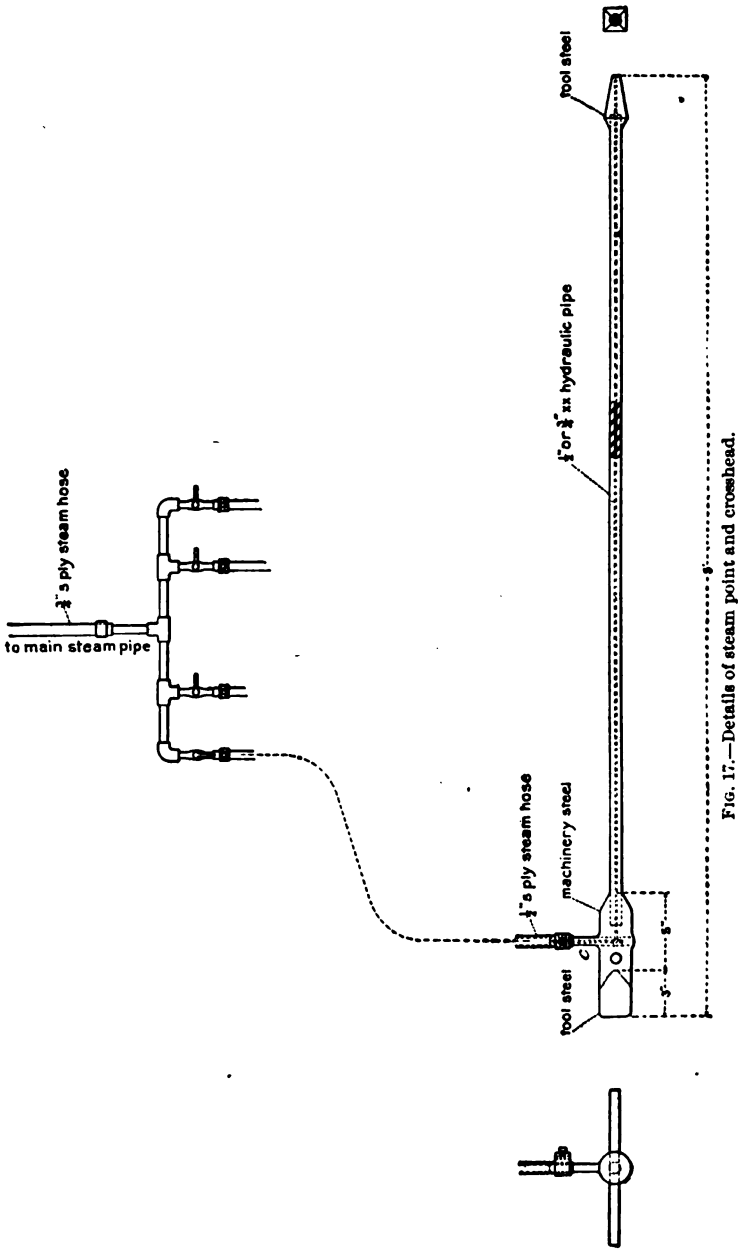



FIG. 17.—Details of steam point and crosshead.

The direct application of jets of dry steam to the gravel bank through the agency of driven pipes has been found to be the most effi-

[a] L'Or en Sibérie orientale. The formula used is: Each breadth of 1 inch of wood applied at the foot of the face thaws an equal width of gravel.

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cient method in general practice for thawing frozen gravel. The amount of moisture contained in steam can be judged by the color of a jet of steam issuing from a small brass pet cock. If it is transparent or whitish near the orifice it contains less than 2 per cent of moisture; if pure white, the moisture is above 2 per cent.

Fig. 17 shows the details of the steam point and some of the fittings which its use entails.

In creek claims exceeding 15 feet in depth where solidly frozen ground occurs, as, for example, in the new Fairbanks district of Alaska, the method of drifting with the use of the steam point is as follows: A 20-horsepower boiler, capable of running 10 steam points, is put on the ground, and frequently one or two extra long points are provided for sinking holes. These long points, from 10 to 12 feet in length, are not so strongly made as the 5-foot points used in the drifting operations. In some cases pieces of one-half-inch hydraulic pipe are used. The point is set up on the ground and steam or hot water is turned on. The time for sinking a hole by this method to bed rock is from twenty-four to forty-eight hours. If large, flat stones are encountered in the gravel underlying the muck it is sometimes advisable to use strong, specially made points to prevent breaking. The average radius of a vertical shaft thus thawed by a single point is 2 feet, and the hole when cleaned out has a cylindrical or tube shape.

If timbering is required after the shaft is sunk it is generally found that the hole will thaw sufficiently to allow the shaft to be carried 4 by 5 feet or 4 by 6 feet inside the timbers. As a rule, however, winter shafts are not timbered. When bed rock is reached a tunnel or runway is run for a distance varying from 50 to 100 feet from the tunnel lengthwise of the claim. From this central drift, which is generally timbered, lateral drifts are run to a distance not exceeding 50 feet, or from this down to 10 feet, or the width of the pay streak. Two tunnels parallel with the central runway are carried at the ends of the cross drifts and connections made from them to the shaft. These are rarely timbered.

The frozen condition of the overburden allows a firm roof to stand without timbering while the gravel is being extracted. This is a great advantage and in part offsets the difficulties attending the breaking up of the frozen gravel. The ground is now ready for working. The drifts and main ways are run as low as possible in cases where the pay is thin, but a height of 3½ feet is the lowest that can be worked with economy.

During the night shift sufficient gravel is thawed to occupy the men in extracting it in the daytime. In handling, not only the picking and shoveling from the bank must be allowed for, but the wheeling to the shaft, the time of return to the face, and the hoisting of the

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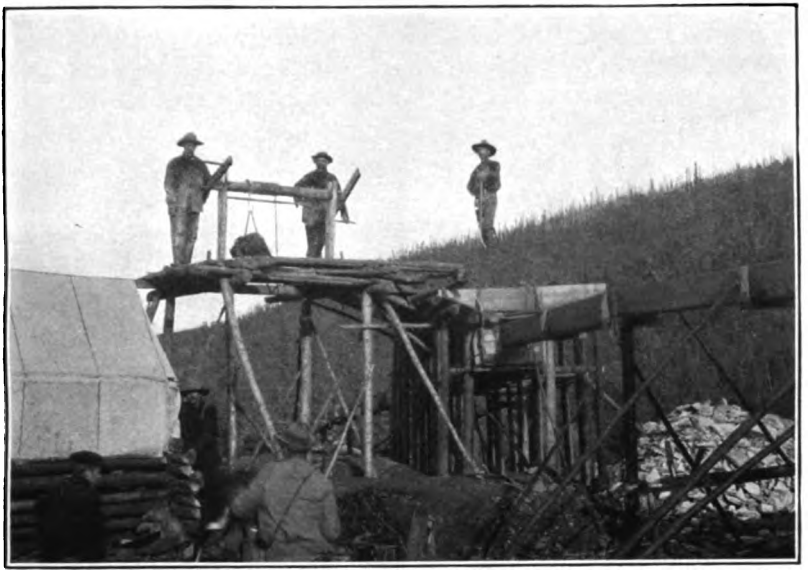
gravel to the surface and conveying to the dump. The face exposed by the cross drift at the far end of the runway is worked back toward the shaft, and the gravel is trammed in wheelbarrows to the shaft and hoisted. Points 5 feet in length are used to thaw the gravel, and are generally used in "batteries" or "crossheads" of four (see fig. 17, p. 90). The points are supplied with steam from a crosshead of iron gas pipe, three-fourths inch in diameter, fitted with elbows and short pieces of one-half inch pipe leading to the steam hose, to which the points are attached. The valves are generally set in these short pieces of pipe. The points are driven in with a mallet by the point man working on the night shift. The points are left in the bank from ten to fourteen hours. The thawing is nearly always done on the night shift, the only men occupied being the point man below and the fireman at the boiler above. Each point thaws a block of gravel on an average 6 feet into the bank, 18 inches on each side of the point and 4 feet high. The crosshead is laid on the floor of the drift, at a distance of 10 feet away from the face, and the steam hose connecting each cock of the crosshead with the individual points must be long enough to reach the desired distance for placing the point in the bank. The cross pipe *c*, to which the hose clamp attaches the hose, should be carried through the steel head and brazed on the opposite side so that it will not break off by a chance blow from the mallet.

It is considered good practice as a rule to start the points with hot water turned through the hose. The points must be driven carefully and slowly, and for 10 points distributed along a face the average time needed is from one to three hours. The amount of steam required for each point has been found to vary in amount from 1 to 2 boiler horsepower. One and one-half may be taken as a safe average. The amount of gravel which a point will thaw appears to vary with the length of the point, and this is regulated somewhat by the character of the gravel. The 5-foot point has been found the most economical size for the small operator.

A typical illustration of the efficiency of the points in the Fairbanks district is the experience at No. 8, below Fairbanks Creek. Points of Dawson manufacture, 5 feet long, costing $15 each laid down, were used in crossheads of four. They were put in at distances of from 2 feet 6 inches to 3 feet apart. The points were started with hot water, and it took three hours to drive them in. A 12-horsepower boiler supplied the steam for 10 points, three-fourths of a cord of wood being burned on the night shift, when the thawing was done. In twelve hours the 10 points thawed a block of gravel 30 feet in length by 5 feet in height by 6 feet into the bank—an average of 3.3 cubic yards to the point.

The above is a little high for the average duty in the Fairbanks district, but is low for the Klondike creek drifting operations. A typical

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*A.* DRIFT MINING ON FAIRBANKS CREEK.



*B.* HYDRAULICKING, SILVER BOW BASIN.

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result on Hunker Creek, where 1¼ to 1½ horsepower was used for each 5½-foot point running ten hours, was 4½ cubic yards. Pl. III, *B* (p. 40), shows a winter drifting operation in the Klondike, and Pl. XV, *A* (p. 92), shows a drifting operation during summer on Fairbanks Creek. Pl. XIV, *B*, shows a battery of steam points thawing ground in the open in preparation for excavating by a steam shovel. Three cords of wood, at $13 per cord, were burned in twenty-four hours to generate steam for operating 15 of these points 10 feet long. These thawed ground 14 feet deep to bed rock. As 4 cords of wood were burned in addition on the steam shovel, and 20 men, at $6 a day, were employed in the twenty-four hours to get out less than 500 cubic yards a day, the operations were not economical. In connection with a dredging operation the thawing by means of steam conducted through gas pipe in 11-foot lengths was estimated to add 40 cents per yard to the cost of working the ground.

The only drifting and steam-thawing plant at Nome gave an efficiency for each point of only 1¼ cubic yards. The points were using in this case a little less than 1 horsepower each and were run only for eight hours. Moreover, the gravel was small and was mixed with much ancient beach sand, which in a frozen condition is extremely difficult to thaw with steam.

The method of thawing with hot water by means of a force pump set in the underground workings, which forces hot water through a small nozzle against the bank, has been tried successfully in the Klondike district. At a claim on Gold Run, where it was desired to extract a 3-foot pay streak of gravel capped by 27 feet of barren gravel at a depth of 50 feet below the surface, a small force pump of the ram pattern, with outside packed valves, was placed in the main runway near the shaft. It drew water from a 6-foot sump near at hand, to which the workings drained. The pump had 4-inch intake, 3-inch discharge choked to 2½-inch, and the water was pumped to the face by means of cotton hose and discharged through a 1-inch brass nozzle at 40 pounds pressure. Six thousand gallons of water were used over and over, and by discharging the exhaust from the pump into the suction the water was kept at a temperature of 150° F. In a shift of ten hours the pump, using 30 horsepower, thawed and broke down ready for the shovelers 175 cubic yards of gravel. This is vastly superior to the average Klondike duty of the 1½-horsepower steam point, even allowing 4 cubic yards to the point, as the 30 horsepower would supply only 20 points and the maximum duty would be 80 cubic yards.

Only under certain very favorable conditions, however, can the hot-water method be used. There must be no silt in the gravel, otherwise the water becomes thick and can not be settled in the sump. If the bed rock is in large flakes, and the pay sinks into it, the hydraulic

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method is inefficient in thawing the valuable ground. The method is worthy of the serious attention of the Fairbanks placer miners, however, as will be pointed out in the discussion of that district (p. 97).

## HOISTING.

For hoisting and conveying, say to a distance not exceeding 200 feet, the Dawson self-dumping carrier, with accompanying bucket, cables, etc., and steam hoist, must be used in order that the most economical work per man employed can be done. This device, which is shown in fig. 18, is without doubt the best system of handling gravel from a shaft of shallow depth now in use in the Northwest. It is strong and compact, and is simple in operation. Those parts which by their position receive the most strain and jar can be made sufficiently durable to withstand hard usage.

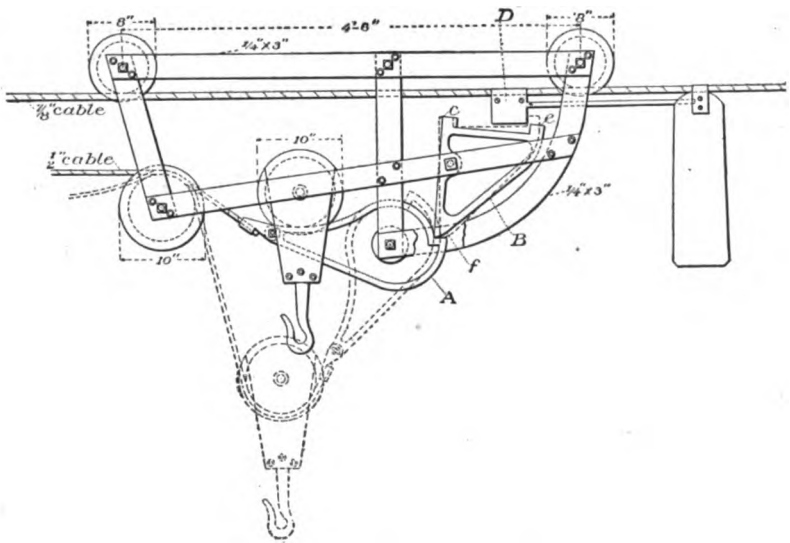



FIG. 18.—Dawson self-dumping carrier.

No springs are used in the construction, for the reason that at low temperature, say of 40° F. below zero, metals are very brittle, and the constant jar, a necessary accompaniment of the work of this apparatus, renders springs and any light metallic member unsafe.

As fig. 18 shows clearly the construction of the carrier, only a few words need be said of its operations.

It may be stated that three distinct operations are accomplished, two of which are performed by the carrier, the third being effected by an auxiliary rope used in dumping the bucket. The first consists in engaging the bucket as it arrives from the shaft and carrying it to the dump box, the second in returning the bucket to the head of the shaft and there dropping it to the bottom. As the carrier returns down

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the seven-eighths inch cable, the hook to which is attached the bucket occupies the position indicated by the solid line. The cam, A, lies horizontally and is held firmly in this position by the dog, B, the weight of the bucket pressing the notch of the cam against the point of the dog, *f*. When the carrier reaches the head of the shaft the end, *c*, of the dog strikes the block, D, and frees the point of the dog from the notch of the cam. The front of the cam now occupies the position indicated by the dotted line, and, as the bucket sinks into the shaft, is pressed against the block, since the carrier tends to move backward. Thus as the bucket sinks with the hook on the one-half inch cable the carrier is held firm.

As the bucket rises from the shaft or pit, the strain is toward the engine, and the lower end of the dog, *e*, still prevents the apparatus from moving.

When, however, the cam, A, by the upward movement of the bucket, reaches the horizontal position indicated by the solid lines, the point of the dog, *f*, jumps into the notch, lowering at the same time the point, *e*, which allows the carrier to move up the seven-eighths inch conveying cable, and also once more secures the cam in its horizontal position.

The block attached to the cable is held in a vertical position by a suspended log or block, which insures its engaging with the dog.

By this system of working, if the self-dumping rig handles 250 of the 30-pan buckets in ten hours or, roughly, 60 cubic yards, the plant will necessitate the employment of 12 men, namely, 2 firemen, 1 hoist man, 1 point man, and 6 men shoveling and wheeling, beside the foreman. The ordinary set-up of the self-dumper is shown in fig. 13. The boiler used for generating the steam for points at night is used for running the hoist in the daytime. In running from 15 to 20 points at night it will burn a cord of wood, and in hoisting in the daytime will burn from one-half to 1 cord more. The total daily twenty-four-hour expense can not be brought below $130 and will probably amount to $150. It is evident that with such a plant the tenor of the gravel must amount to at least $2.60 to the cubic yard to pay any profit at all, exclusive of washing in the spring, and should be 4 cents to the pan, or $5.20 to the yard, to pay a profit which compensates for operating in so remote and expensive a country. The cost of washing in the spring is in general from 50 cents to $1 per cubic yard.

The winter dumps are piled in a conical heap around the gin pole, to which the trolley cable of the self-dumper has been attached while the dumping is in progress. In laying out the space for the dump, the string of boxes in which the gravel is to be washed during the following spring is so laid that it will bisect the proposed cone, having its proper grade and length. When the spring opens the dump is

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easily shoveled into the boxes, from both sides, beginning at the lowest point and working upward. Boards are generally laid over the top of the boxes, and a portion of the gravel rests on these. The boards are taken off as the work of shoveling in progresses.

The expenses of winter work are much greater than those for summer, and the tenor of the gravel must in consequence be much higher. In the first place it is to be remembered that the gravel dumped in winter must be all rehandled in the spring. In thawing also the amount of steam used in winter is greater than in summer, and all pipes and hose conveying steam both above and under ground must be coated with asbestos or other nonconducting material. On the other hand, labor is generally cheaper in winter than in summer, and the possibility of striking thawed streaks of ground is much less.

### DRIFTING IN THE FAIRBANKS DISTRICT.

As has been stated, the only mining practiced at Fairbanks is creek mining. In the open season, although the bulk of the ground can be worked by drifting, a smaller proportion is workable by open cutting. By far the larger portion of the ground must be worked by drifting on account of the depth to bed rock and, in many cases, the thinness of the pay. The ground is in the main frozen, but thawed streaks occur. The gravels are of the angular and subangular character which marks all the gravels deposited in recent time in the northwest. The angularity is more pronounced than in the Birch Creek district or the Klondike.

One characteristic feature of the Fairbanks gravel has an important bearing on the method of thawing the frozen gravel. This is the fact that while the layer of so-called muck is comparatively thin, from 2 to 7 feet in the workings on the creeks themselves, exclusive of the slopes, the gravels, which are from 6 to 15 feet in thickness, do not carry pay throughout their section, but only in the lower part. The pay is sometimes as thin as 6 inches in the gravel, and rarely exceeds 3 feet. It is then frequently necessary to take only a portion of the gravel down, and to run the drifts as low as possible, i. e., not to exceed 3½ feet. To do this economically, and so that the top and barren gravel will not be continually caving and falling during the drifting, the ground must either be timbered or the method of steam thawing must be abandoned. Another reason why the method of steam thawing has a limited application in the Fairbanks district is the fact that the gravel is very argillaceous in its pay portion, and the thawing and drying with the steam result in a baking of the ground. Thus the gravel which was frozen becomes in its dry state cemented, and the difficulty of getting it out is not avoided but only lessened.

Thawing by means of hot water driven through a force pump and conducted to the bank by means of cotton hose and piped against the

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bank by means of a small fireman's nozzle is the most successful method which has been so far tried to thaw ground under the above-mentioned conditions. As regards the heating of the water, the system adopted at Fairbanks is to conduct the exhaust steam of the pump back into the suction of the pump as it draws water from a sump alongside of it. This has been found more effective than simply turning the exhaust pipe directly into the sump itself. The water used is sometimes supplied in sufficient quantity from the mere seepage from the ice mixed with the thawed gravel. But sometimes it will have to be introduced in the pit in small quantity. On the other hand, especially where thawed streaks occur naturally in the gravel, the water must be pumped out. This is done by the same pump used for the hydraulicking, without changing its position.

This method of thawing by hot water piped against the bank has two advantages. The strongest appears to be the fact that gravel thawed by this method can, as it were, be selected in the face, and no higher gravel than may be profitable need be taken down. The portion of the gravel above the part taken down remains solidly frozen, and consequently the roof of the drift or wide stope does not cave any worse than does the roof of solid muck in drifting operations where all the gravel in its complete vertical section is extracted. Another advantage is that the gravel is moved from its original position farther than by steam, and if it contains clay the clay has less opportunity to bake and cake than with steam thawing, and the amount of hand work in picking down the gravel is lessened.

A serious objection to thawing by hot water may justifiably be raised in cases where the bed rock consists of large slabs of schist, into which the gold sinks from 1 to 4 feet and even more. In such a case the water can not be piped to reach all the frozen gold-bearing material. Although I am not aware that a combination of the hot-water and steam-thawing methods has been tried in such a case as the above, it seems not impossible that such a combination would be the most economical. On the other hand, where the bed rock consists of finely comminuted schist or softened, thoroughly rotten rock, even should the gold be found in it to the depth of 2 feet, there can be no valid objection to the hot-water hydraulicking method. In the Nome district of Seward Peninsula, where the hot-water method was tried, it was found that the water finally became too thick with sediment to be used in the pump, and the system was abandoned.

A minor recommendation for the use of the hot-water method is the fact that all the unpleasantness of the steam method, which fills the workings with steam, creates dampness, etc., is obviated, and the walls and roof of the drifts are dry, while ditches cut in the bed rock on grade to the pump sump can be so cut as to prevent the floors from



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being wet. The obscurity of the air in the workings by steam, especially in the early part of the day shift, is frequently a source of danger, as the roof can not be watched so closely as it could were the air clear, and consequently slabs of the roof that are ready to fall can not be easily seen, so that the liability that men will be crushed is greater.

I should especially recommend the method of hot-water thawing to the consideration of the miners of Cleary and Pedro creeks, while on Fairbanks Creek, as hitherto developed, the method of thawing with steam points seems more applicable.

In the Fairbanks district shafts sunk for work in the summer time are in nearly all cases timbered, either wholly or partially. In very deep shafts, as, for example, on the left bank of Cleary Creek near the junction with Chatham, where 40 feet or more of solid muck is encountered, timbering does not appear to be always necessary throughout the whole of the shaft. The muck forms a wall which resembles in its consistency a wall of solid ice, and in working throughout a season of four months, with the shaft in constant use, there will be little caving of the walls. All shafts that extend 20 feet or less, however, especially where gravel composes half or more of the section—shafts intended for working out a block of ground, conducting steam connections, pump connections, and connections for hoisting—should be securely timbered.

In view of the local conditions, the following method of timbering appears the most satisfactory. After the hole is sunk to the required depth by thawing, a square set with 6-foot centers—or should the shaft be 4 by 6 feet, of this dimension—is put in at the bottom. Three-inch pole lagging, with cross sets of 6-inch timbers inside at 6-foot intervals, is carried up to the collar. Inside the sets 6- or 12-foot poles, 3-inch, are nailed in the four corners to the cross sets. Moss is laid up outside the pole lagging, as dry as possible, and packed against the gravel or muck walls. In cases where it is impossible to sink without timbering as the shaft is sunk the timbering is carried down, and the lagging is driven as each set progresses, the square set being put in at the bottom on the completion of the shaft. Shafts timbered in this manner have been found to stand for periods of from one to two years, as long as the work in the Fairbanks district has been in progress, and there is no reason why they should not stand much longer. Timbering of this sort can be done for the most part with the ordinary cord wood delivered for fuel, and this is much the cheapest method available.

The cribbing method is sometimes adopted, accompanied by the same packing, with moss outside the cribbing. It is, however, more expensive, and in a shaft of considerable depth is much more likely to get out of plumb in this frost-ridden country.

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In the Fairbanks district it has not yet been found necessary to timber the underground workings to any great extent. The main runway, if it is to be used for the whole season or for a period exceeding a month, should be timbered for safety. Six-foot sets of posts and caps only, with lagging over the roof, are generally sufficient. Pole lagging is cheaper and more advisable than split lagging. The caving system, working always toward the shaft, allows the faces to be carried forward without timbering of the stopes. The elaborate timbering methods necessary in the Klondike benches and in many parts of California in drifting operations are happily not needed in this portion of Alaska, and are not likely to be required in any extension of the Tanana area. No case has been seen in the operations, as thus far developed, where false sets were carried in taking out the gravel. When the operations at Fairbanks become more extensive, however, and drifting is carried on more systematically with wide faces, it is very likely that the workings will require timbering. At present it is not possible to give the cost of this work, as the figures were not obtainable.

## HYDRAULIC MINING.

### GENERAL REMARKS.

The hydraulic method of working gold gravel deposits is the most economical method from the standpoints of power, capacity, and labor. It is, on the other hand, exceedingly wasteful of water, and the topographic conditions under which it may be successfully and profitably conducted are not of common occurrence, even in mountainous districts.[a]

The hydraulic method of mining was invented by Edward E. Matteson, a native of Sterling, Conn., and applied by him to the auriferous gravels in California in 1852.[b] One or more jets of water under pressure are thrown from a pipe or pipes with great velocity against the face of a gravel bank, and the gravel is loosened by the stream so that it falls or "caves." The gravel is struck with sufficient force to be disintegrated and broken up so that it can be carried by the current into the sluice if the bed rock has a sufficient grade. For assistance in moving and washing the gravel after it leaves the bank, additional

[a] The amount of water used in hydraulicking is shown by the following illustration: Three hundred million gallons of water a day are used at present for the supply of Greater New York City, or 26,666 miner's inches, of twenty-four-hour service. Taking the duty of an inch at 2 cubic yards, and a tenor of 15 cents in gold per cubic yard, the above amount would supply only 13 hydraulic mines, each using 2,000 miner's inches under head. The total amount of gravel washed would be 52,000 cubic yards per day, and the product $7,800; or (with a season of one hundred and twenty days) annually, 6,240,000 cubic yards, and a product of $936,000, an amount not startlingly large, considering the magnitude of the operations involved.

It is to be expected that persons with a limited knowledge of hydraulic mining will object to the low capacity and short season assumed in the above, but operators of long experience will realize that the conditions and results are assumed, if anything, more favorable than is found in average practice.

[b] Whitney, J. D., The auriferous gravels of the Sierra Nevada of California: Mem. Mus. Comp. Zool. Harvard Coll., vol. 6, 1880.

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water is frequently used under slight head, and is known as "bank head" or "by-wash" water. Various devices for more easily disintegrating the bank and for disposal of the large bowlders and of tailings where natural grade is lacking will be later discussed.

In California the application of hydraulic mining spread with great rapidity, especially within the drainage basins of San Joaquin and Sacramento rivers. This method was adopted also in other portions of the western United States and in other parts of the world, particularly in Australia and New Zealand. In the part of California referred to, extensive operations ceased, not because the gravel deposits were exhausted, but because of economic considerations other than those of mining. The passage of an act of Congress in March, 1893, entitled "An act to create the California Débris Commission and regulate hydraulic mining in the State of California," sounded the death knell of the huge mining operations which had changed the topography and blanketed many square miles of arable lands in the San Joaquin and Sacramento valleys with gravel tailings.

The comments of J. D. Whitney,[a] written in 1880, concerning the application of hydraulic mining to California conditions, are as follows:

> It is owing to a happy combination of favorable circumstances that the system of hydraulic mining has been so successful on the slopes of the Sierra Nevada. That the peculiar set of conditions which makes hydraulic mining possible is not often met with is sufficiently proved by the fact that this system, which seems so admirably adapted to the needs of the Californian gravel miners, has hardly been at all successful in any other region. It has been tried again and again in the southern United States with almost unvarying loss; and even in Australia, where the mode of occurrence of the gold is in many respects so similar to what it is in California, there are few districts where the hydraulic method can be applied.
>
> The first great need of the hydraulic miner is an abundance of water and with a considerable "head," so that the stream may issue with sufficient velocity from the pipes.
>
> An abundance of water can not be secured without extensive engineering operations and the expenditure of a large amount of money. Extensive reservoirs must be constructed by building dams across the outlets of the mountain valleys, so as to impound the water coming from the melting of the winter's snow on the high Sierra, and the necessary canals—or ditches, as they are universally called by the miners—must be excavated to carry the water to the points where it is needed for use. The long, rapid, and rather uniform slope of the Sierra, in the mining districts, makes it possible almost everywhere to carry the ditches with such a grade and in such a position as to allow the water to be taken from them at a sufficient elevation to give the necessary head at the point of working. The great elevation of the important gravel masses and the deep canyons into which the whole mining region is cut up, afford, in almost every locality, the necessary facilities for arranging the sluices and disposing of the tailings.

A need equally as great, not sufficiently emphasized by Whitney, is adequate grade or slope of the bed rock for the moving of material. Experience has shown that the lightest grade of stream bed upon

[a] Loc. cit., p. 62.

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which hydraulic operations may safely be undertaken is 220 feet to the mile.

The above statements regarding hydraulic mining are as worthy of consideration to-day as when they were written. Bench deposits, as already defined, are those above all others to which the hydraulic method is most likely to be successfully applied, because adequate grade for the disposal of tailings can be secured. Deposits in the beds of present streams, on the other hand, are exploitable by hydraulicking to a far less extent. In Alaska extensive bench deposits do not occur, even in the alpine districts of the south coast, and, moreover, where auriferous benches are found they are not backed by high mountains from which the water under pressure can be obtained. The bench deposits of Alaska are not characterized by great thickness as are those of California. A depth of 10 feet of auriferous gravel with 20 feet of overlying barren silt, or a total of 30 feet, is a not uncommon condition in Alaska, while in California gravel banks of 75 to 500 feet in thickness occur and have been worked by hydraulicking. The hydraulic operation shown in Pl. XV, *B* (p. 92), is on a lake bed, locally formed in a portion of Silver Bow basin, Juneau district.

The hydraulic principle implies the breaking down of all the alluvial material by water under pressure, the cheapest power. It is evident that unless the gold is distributed throughout the vertical section of the alluvial deposit, as well as on and in the bed rock, the greatest amount of material is hydraulicked off at a loss. In general the pay dirt in Alaska composes less than 15 per cent of the bank, measured vertically. In California gravels, on the other hand, much more frequently a small amount of gold occurs throughout the whole bank.

In Alaska attempts have been made to work very shallow ground, in some cases of 5 feet section, by hydraulic methods involving the construction of ditches and installation of machinery at a cost of $100,000 and over. Unless the gravels worked were much richer than previous workings in the vicinity, it was impossible to see how the enterprise could by any means be profitable. Simple mechanical plants, requiring a comparatively small investment, could have handled the small body of gravel fully as fast and in the long run more cheaply. It is undoubtedly true that many men are deterred from installing really economical plants of a mechanical nature by the desire to apply the spectacular methods of the hydraulic miner, without regard to the existing conditions.

A word should be said about the application of power to produce pressure for hydraulicking.[a] Several plants where this principle is applied have been visited in Alaska and the neighboring British territory. Nine plants were seen and it was not clear that any plant pump-

[a] These statements do not refer to the hot-water method of hydraulicking frozen gravel.

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ing water for hydraulic mining was making expenses. Some Nome operators are of the opinion that if crude oil can be obtained for $2 a barrel the gas engine can be profitably used to hydraulic certain rich patches of the coastal plain gravels, using 50 to 60 pounds pressure at the nozzle. Only under the most exceptional conditions would such an application of the hydraulic method be profitable. It may be truly said that 95 per cent of all attempts to pump water in hydraulic gravel mining, in whatever portion of the world they have been tried, have been failures. The miner who contemplates such an operation in a remote region where coal costs $30 a ton or wood $15 a cord had better first exhaust the possibilities of all other methods of moving gravel which circumstances or ingenuity can suggest.

It must not be assumed that the tenor of the gravel in Alaska is greatly above that of the auriferous gravels formerly worked so extensively in California, especially where it is necessary, as in hydraulicking, to distribute the value contained in the thin-bottom pay streak throughout the whole of the vertical section of gravel which must be moved.[a] There is a widespread opinion, amounting to a dictum, that the hydraulic method should be installed in preference to others wherever there is the slightest chance for its success. That this chance is small in the hitherto developed portions of Alaska the present account will make clear. Capital invested by the miner in expensive water conduits in Alaska is not recoverable except from the profit on his operations. The ditch builder can not enter the domain of commerce and sell his water or the power generated thereby, as do many of the water companies in populous agricultural and industrial communities. In rare instances only can he even sell it to miners. On the exhaustion of his own auriferous ground, his ditch and plant becomes practically valueless.

While hydraulicking river and creek beds in Alaska with the necessary accompaniment of some form of lifting operation for the tailings is not to be entirely decried, it should be undertaken with extreme caution. The ever-present danger of floods and the expense of wing dams must be considered. The tailings will be raised by the water lift primarily, and the method of using this in gravel mining will be fully described. The operator should bear in mind, however, that the introduction of the water lift decreases by over 60 per cent the duty of the unmodified hydraulic method as above described; also that the

[a] For example, Whitney states (loc. cit., p. 118) that the area hydraulicked off at Todds Valley, Placer County, Cal., was 1 mile by one-fourth mile in area, and the gravel from 35 to 75 feet in thickness, a total of nearly 9,000,000 yards, with an estimated yield of $4,000,000, or about 44 cents per cubic yard.

At the Excelsior claim, near Placerville, Eldorado County, Cal., 20 acres of ground were washed off with an average thickness of from 40 to 60 feet of pay gravel. The yield was estimated at $5,000,000, about half of which was taken out by drifting and the other half by hydraulicking. Mr. Alderson, the principal proprietor, estimated that the yield of the Excelsor gravel was $1 per cubic yard. A single placer claim of 20 acres, containing so large an amount of gold as the Excelsior claim, has yet to be discovered in Alaska.

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use of the ingenious device entails a new set of difficulties with which his previous experience in hydraulic mining will hardly have fitted him to deal. An unfortunate instance was seen in one of the remote districts of Alaska, where a hydraulic elevator of 5 tons weight had been imported at a cost of nearly $2,000 and was found useless because insufficient water to operate it was obtainable, although a ditch and flume line had been constructed at a cost of $15,000. The elevator lay on the bank, and a makeshift had been improvised from a piece of sheet-steel pipe and a fireman's brass nozzle.

That hydraulic operations are and have been successfully prosecuted in Alaska is not to be denied. The cautionary remarks which have been made will serve as a reminder, however, that the moving of large bodies of gravel by water under natural head is not always as cheaply accomplished as a casual inspection of such operations would induce one to believe. In any event, a hydraulic installation, under conditions where the cost of leading water runs into the thousands of dollars per mile, should not be undertaken until due consideration as to the possibility of using other methods has been given.

## DITCHES, FLUMES, AND RESERVOIRS.

In table 8 an attempt has been made to show in concise form the principal facts regarding the construction of water conduits in Alaska and the North. So great was the extent of territory covered that opportunity for measurements and calculations was only occasional. The statements of operators were generally accepted; they were rejected only when they were palpably misleading. When not otherwise indicated, the data shown were supplied by the operators. When the data were based on subsequent estimates, the figures are starred.

It can not be too strongly stated that the tables in this report are based on statements of operators and are not the result of detailed investigation of properties. The collection of data for this report necessitated the covering of a vast extent of territory in four months' time. The data are as complete and as nearly accurate as the circumstances allowed. Estimates based on the cost of water conduits as given below, and the amount of water available, should take into consideration the degree of authority which attached to the compilation.

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TABLE 8.—*Water conduits in Alaska and the North.*

| Locality. | Ditches. | | | | | | | | | Notes. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Length earth work. | Length rock work. | Grade per mile. | Width. Top. | Width. Bottom. | Depth. | Average amount of water used, miner's inches (1.5 cu. ft. per min.) | Greatest head. | Cost of construction per mile. | Annual cost of maintenance per mile. | |
| | | | | *Feet.* | *Feet.* | *Feet.* | | *Feet.* | | | |
| South Coast Alaska: | | | | | | | | | | | |
| Douglas Island | | | | | | | | | | | |
| Gold Creek | | | | | | | | | | | |
| Do | | | | | | | | | | | |
| Silver Bow basin | | | | | | | | | | | |
| Windfall Creek [a] | | | | | | | | | | | |
| Lemon Creek | | | | | | | | | | | |
| Sunrise district: | | | | | | | | | | | |
| Miller Creek [a] | 2 miles | | 18 feet | | | | 1,500 | 110 | | | |
| Crow Creek [a] | 1 mile | | 26 feet | 5 | 3 | 2 | | | | | |
| Atlin, B. C.: | | | | | | | | | | | |
| Pine Creek | 4½ miles | | 8 feet | 12 | 6 | 4 | 1,500 | 185 | $3,520 | | |
| Do | 5½ miles | | 8 feet | 9 | 4 | 3 | 1,000 | 162 | 3,000 | | |
| Do | 3 miles | | 8 feet | 7 | 4 | 3 | 700 | 350 | | | |
| Birch Creek | | | | | | | | | | | |
| Spruce Creek | 2,000 feet | | 5 feet | 9 | 4 | 5 | 900 | 200 | | | |
| Do | 1½ miles | | | 7 | 4 | 2½ | 1,200 | 200 | 5,200 | | |
| McKee Creek | | | | | | | | | | | |
| Do | | | | | | | | | | | |
| Do | | | | | | | | | | | |
| Do | 3,300 feet | | 26 feet | 9 | 3 | 2½ | 1,000 | 325 | 5,220 | | |
| Porcupine district: | | | | | | | | | | | |
| Porcupine Creek [a] | | | | | | | | | | | |

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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dawson district, Y. T.: | | | | | | | | | | | |
| Miller Creek [a] | 9½ miles | | 8 feet | 8½ | 3½ | 3½ | 1,200 | | | | |
| Do | 8.6 miles | | 8 feet | 5½ | 2½ | 1½ | 600 | | | | |
| Bonanza Creek | | | | | | | | | | | |
| Do | 9,400 feet | | 13.7 feet | 5 | 3 | 1½ | 100 | | | $350 | Cost, ditch, flume, and siphon, $12,000. |
| Do | 2 miles | | 7 feet | 5 | 2 | 3 | 150 | 150 | | | |
| Do | 8 miles | | 8 feet | 6 | 3 | 2 | | | 1,500 | | Ditch under construction. |
| Eldorado Creek | 6 miles | | 10 feet | 8 | 4 | 3 | 120 | 120 | 3,000 | | |
| Hunker Creek | 4 miles | | | 3 | 2 | 2 | 150 | 20 | 2,500 | 150 | |
| Do | 5¼ miles | | | 3 | 2 | 1½ | 100 | 40 | 2,000 | | |
| Eagle district: | | | | | | | | | | | |
| American Creek | | | | | | | | | | | |
| Fortymile district: | | | | | | | | | | | |
| Wade Creek [a] | 1 mile | | 8 to 9 inches | | | | 120 | | | | |
| Do | 400 feet | | 2 to 13 inches | | | | 200 | | | | |
| Birch Creek district: | | | | | | | | | | | |
| Deadwood Creek | 750 feet | | | | | | 120 | | | | |
| Do | 3,000 feet | | 6 to 8 inches | | | | 120 | 65 | 800 | | |
| Do | | | | | | | | | | | |
| Mastodon Creek | | | | | | | | | | | |
| Fairbanks district: | | | | | | | | | | | |
| Fairbanks Creek | 900 feet | | | 2 | 2 | 1 | 100 | | 5,800 | | |
| Do | 3,000 feet | | 4 to 5 inches | 5 | 4 | 1½ | 150 | | 6,330 | 500 | |
| Cleary Creek | 500 feet | | 3 feet | 3 | 2 | 1½ | 75 | | 2,500 | | |
| Do | 1½ miles | | 3 feet | 3 | 2 | 1½ | 50 | | 3,200 | | |
| Do | 1 mile | | 3 feet | 3 | 2 | 1½ | 50 | | 2,000 | | |
| Rampart district: | | | | | | | | | | | |
| Hoosier Creek [a] | 3,500 feet | | 3 to 4 inches | 8 | 6 | 1½ | 350 | 75 | [b] 10,500 | Expensive. | |
| Pioneer Creek [a] | 3½ miles | | 3 to 4 inches | 5 | 4 | 1½ | 300 | | [b] 3,750 | | |
| Nome district: | | | | | | | | | | | |
| Nome River [c] | 17 miles | | 3.37 feet | 11 | 8 | 3 | 1,000 | 360 | 2,300 | 300 | $300,000 total cost, including annual maintenance for 4 years. |
| Do | 26 miles | 5 miles | 4.5 feet | 14 | 10 | 3 | [d] 2,000 | | [e] 3,000 | | |
| Do | 5 miles | 1,800 feet | 6.5 feet | 11 | 8 | 3 | 2,000 | | [e] 2,300 | | |

[a] Not visited. [b] Ditch and flume. [c] See special description of the Miocene ditch (pp. 123–126). [d] On Aug. 23, 1904, measured 1,752 miner's inches. [e] Ditch.

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TABLE 8.—*Water conduits in Alaska and the North*—Continued.

| Locality. | Ditches. | | | | | | | | | | Notes. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Length earth work. | Length rock work. | Grade per mile. | Width. Top. | Width. Bottom. | Depth. | Average amount of water used, miner's inches (1.5 cu. ft. per min.) | Greatest head. | Cost of construction per mile. | Annual cost of maintenance per mile. | |
| Nome district—Cont'd. | | | | *Feet.* | *Feet.* | *Feet.* | | *Feet.* | | | |
| Basin Creek | 2½ miles | | 10 feet | 7½ | 4 | 2 | 250 | 275 | $1,500 | | |
| Glacier Creek | 5 miles | | 5 feet | 4 | 3 | 1 | 115 | 25 | | | |
| Dexter Creek | | | | 5 | 3 | 1 | 120 | | | | |
| Cripple River | 4 miles | | 4.5 feet | 8 | 6 | 1 | 775 | | 2,500 | | |
| Council district: | | | | | | | | | | | |
| Ophir Creek | 4 miles | 1 mile | 4 feet | 9 | 6 | 2 | 1,000 | 192 | [a]4,000 | | |
| Do | 13 miles | 5 miles | 3.3 feet | 16 | 10 | 3 | [b]3,300 | 200 | [c]6,000 | $330 | Cost, $8,000; includes 26-inch pipe line, 8,500 feet; total cost, $200,000. |
| Do | 6 miles | | 3.3 feet | 8 | 5 | 2 | 600 | | 3,000 | | |
| Do | 1½ miles | | 5.3 feet | 9 | 6 | 2 | 150 | | 5,330 | | Includes rock cuts. |
| Do | 2½ miles | 400 feet | 3.3 feet | 9 | 6 | 3 | 1,500 | 100 | | | Total cost ditch, flume, and trestle, $30,000. |
| Do | 8 miles | | | | | | | | | | |
| Gold Bottom | 1 mile | | | 3 | 2 | 1½ | 100 | 60 | [d]1,000 | | |
| Solomon district: | | | | | | | | | | | |
| Solomon River | 9 miles | | 5 feet | 12 | 10 | 3 | | 125 | 8,000 | | Mile cost includes allowance three-fourths mile rock cut; 7½ miles more under construction. |
| Do | 6½ miles | | 4 feet | 16 | 12 | 5 | 1,200 | 120 | 15,000 | | |
| Port Clarence district: | | | | | | | | | | | |
| Sunset Creek [e] | 27 miles | | 5 to 8 inches | 15 | 12 | 1½ | 2,000 | | | | Ditch under construction. |
| Klondike River | 41,500 feet | 1,000 feet | 10 feet | 7 | 4 | 2½ | 500 | 300 | 4,330 | | Do. |

[a] Ditch; rock cut, $11,500.
[b] On September 11, 1904, did not exceed 1,600 miner's inches.
[c] Ditch; rock work, $8,000.
[d] Data estimated.
[e] Not visited.

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TABLE 8.—*Water conduits in Alaska and the North*—Continued.

| Locality. | Flumes. Length. | Grade in feet per mile. | Width. | Depth. | Size of boards. | Size of posts and sills. | Size of stringers. | Average amount of water used, miner's inches (1.5 cu. ft. per min.). | Greatest head. | Cost of construction per mile. | Annual cost maintenance per mile. | Cost of lumber per M. | Average open season. | Notes. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| South Coast Alaska: | | | *Ft. in.* | *Ft. in.* | *Inches.* | *Inches.* | | | *Feet.* | | | | | |
| Douglas Island | | | | | | | | | | | | | | |
| Gold Creek | 4,600 feet | 34.30 | 4 8 | 4 8 | 2 by 12 | 4 by 6, 4 by 4 | | | 200 | $11,616 | | $13.00 | May 15–Nov. 1 | Flume not in use. |
| Do | 1,000 feet | 36.90 | 4 0 | 2 0 | 1 by 12 | 2 by 4 | | 200 | 240 | | | 15.00 | 12 months | Water generates mill power. |
| Silver Bow basin | 3,000 feet | 27.50 | 4 0 | 3 0 | 2 by 12 | 6 by 6, 6 by 4 | | | 150 | | | 15.00 | May 15–Nov. 1 | Flume not in use. |
| Windfall Creek [a] | 5,000 feet | 14.00 | | | | | | 750 | | | | | Apr. 15–Oct. 20 | |
| Lemon Creek [a] | 2 miles | 26.00 | 5 0 | 3 0 | | | | | | | | 7.50 | May 1–Nov. 1 | |
| Sunrise district: | | | | | | | | | | | | | | |
| Miller Creek [a] | | | | | | | | | | | | | May 15–Oct. 15 | |
| Crow Creek [a] | | | | | | | | | | | | | do | |
| Atlin, B. C.: | | | | | | | | | | | | | | |
| Pine Creek | | | | | | | | | | | | | do | |
| Do | | | | | | | | | | | | | do | |
| Do | | | | | | | | | | | | | do | |
| Birch Creek | 1,960 feet | 10.00 | 3 6 | 1 7 | 1 by 8 | 2 by 4 | | 600 | 150 | | | 40.00 | do | |
| Spruce Creek | 2,500 feet | 5.00 | 4 0 | 2 8 | | | | 900 | 200 | | | 40.00 | do | |
| Do | Short sections. | | 4 0 | 3 0 | 1¼ by 8 | 4 by 6 | 4 by 8 inches by 12 feet. | 1,200 | 200 | | | 45.00 | do | |
| McKee Creek | 3,000 feet | 42.20 | 2 6 | 2 6 | [b] 1¼, 1 | 3 by 4, 4 by 4 | 4 by 4 inches by 12 feet. | [c] 2,000 | 170 | | | 45.00 | do | |
| Do | 3,000 feet | 36.90 | 3 4 | 2 8 | | | 4 by 4 inches by 12 feet. | 2,000 | 170 | 9,820 | | 45.00 | do | |

[a] Not visited. [b] Bottom boards and side boards. [c] May 20 to September 1, 2,000 miner's inches; September only, 500 miner's inches.

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TABLE 8.—*Water conduits in Alaska and the North*—Continued.

| Locality. | Flumes. | | | | | | | | | | | | | Notes. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Length. | Grade in feet per mile. | Width. | Depth. | Size of boards. | Size of posts and sills. | Size of stringers. | Average amount of water used, miner's inches (1.5 cu. ft. per min.). | Greatest head. | Cost of construction per mile. | Annual cost maintenance per mile. | Cost of lumber per M. | Average open season. | |
| Atlin, B. C.—Cont'd. | | | *Ft. in.* | *Ft. in.* | *Inches.* | *Inches.* | | | *Feet.* | | | | | |
| McKee Creek | 3,500 feet | 33.20 | 2 8 | 2 8 | | | 4 by 4 inches by 12 feet. | 2,000 | 170 | $9,028 | | $45.00 | May 15–Oct. 15. | |
| Do | | | | | | | | | | | | | do | |
| Porcupine district: | | | | | | | | | | | | | | |
| Porcupine Creek[a] | 1,100 feet | 26.40 | | | | | | 3,330 | | | | 20.00 | May 1–Oct 1 | |
| (?) Creek[a] | 200 feet | | | | | | | 1,000 | 400 | | | 50.00 | do | |
| Dawson district, Y.T.: | | | | | | | | | | | | | | |
| Miller Creek[a] | 3,000 feet | 16.00 | 5 0 | 3 0 | [b]1¼, 1 | 4 by 4, 4 by 6 | | 1,200 | 210 | | | 60.00 | May 25–Sept. 25. | 4,640 feet inverted siphon, 24-inch steel pipe. |
| Do | | | | | | | | | | | | | May 1–Oct. 1 | |
| Bonanza Creek | 1,700 feet | 30.00 | 2 6 | 1 8 | 1 by 10 | 2 by 4 | | 200 | 65 | 4,750 | | | do | |
| Do | 2,600 feet | | 1 8 | 1 6 | 1 by 12 | 2 by 4 | | 100 | | | $150 | 60.00 | do | 2,200 feet inverted siphon, 10-inch pipe, at $1.55. |
| Do | Short sections. | 9.10 | 3 8 | 2 0 | 1 by 12 | 3 by 4 | | 150 | 150 | | | | do | 1,500 feet inverted siphon, 15-inch steel pipe. |
| Do | do | | 4 2 | 2 5 | 1 by 10 | 4 by 4 | | | | 11,880 | | 60.00 | do | Several inverted siphons, 20–26 inch pipe, 16–12 gauge, cost $2.50 per foot laid. |
| Eldorado Creek | 3,000 feet | 10.00 | 2 0 | 2 0 | 1 by 12 | 2 by 4 | [c] | 120 | 120 | 3,000 | | | do | |
| Hunker Creek | | | | | | | | | | | | | do | |
| Do | 3,960 feet | | 1 8 | 10 0 | 1 by 10 | 2 by 2 | | 125 | 50 | 3,000 | | 45.00 | do | |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Eagle district:** | | | | | | | | | | | | | | |
| American Creek | 7,300 feet | 11.50 | 2 | 8 | 2 | 0 | 1 by 8 | 2 by 4, 4 by 4 | 250 | 150 | 10,800 | 75.00 | June 1–Oct. 1 | Trestles, 97 feet high, 300 feet long; 22 feet high, 400 feet long. |
| **Fortymile district:** | | | | | | | | | | | | | | |
| Wade Creek[a] | | | | | | | | | | | | | May 10–Oct. 1 | |
| Do | 1 mile | | | | | | | | | | | | do | |
| **Birch Creek district:** | | | | | | | | | | | | | | |
| Deadwood Creek | | | | | | | | | | | | | June 15–Sept. 15. | |
| Do | | | | | | | | | | | | | do | |
| Do | 1,200 feet | 17.50 | 3 | 0 | 1 | 0 | 2 by 8 | 4 by 4 | 120 | 20 | 1,320 | | do | Built of flatted timbers hewn. |
| Mastodon Creek | 2,000 feet | 2.00 | 2 | 6 | 1 | 4 | 1 by 8 | 2 by 4 | 60 | | [d] 5,000 | 125.00 | June 15–Oct. 1 | Lumber whipsawed, at 15 cents per foot. |
| **Fairbanks district:** | | | | | | | | | | | | | | |
| Fairbanks Creek | | | | | | | | | | | | | May 1–Oct. 1 | |
| Do | | | | | | | | | | | | | do | |
| Cleary Creek | | | | | | | | | | | | | do | |
| Do | | | | | | | | | | | | | do | |
| Do | | | | | | | | | | | | | do | |
| **Rampart district:** | | | | | | | | | | | | | | |
| Hoosier Creek[a] | 800 feet | 3.33 | 6 | 0 | 1 | 6 | | | 350 | 75 | [e] 10,500 | 120.00 | June 15–Oct. 1 | Oregon fir used; ditch in bad ground. |
| Pioneer Creek[a] | 2,000 feet | 3.33 | | | | | | | | | [e] 3,750 | | do | |
| **Nome district:** | | | | | | | | | | | | | | |
| Nome River[f] | | | | | | | | | | | | | June 25–Oct. 10 | |
| Do | 1,110 feet | 9.00 | 8 | 0 | 2 | 9 | 1½ by 12 | 4 by 6 p, 2 by 8 s | 2,000 | 360 | 33,000 | [g] 150.0 | do | 1,600 feet inverted siphon, 40 inches diameter; cost $10,000. |
| Do | | | | | | | | | | | | | do | |
| Basin Creek | | | | | | | | | | | | | do | |
| Glacier Creek | | | | | | | | | | | | | do | |
| Dexter Creek | | | | | | | | | | | | | do | |
| Cripple River | | | | | | | | | | | | | do | |

[a] Not visited.
[b] Bottom boards and side boards.
[c] Posts, sills, and stringers, not sawed.
[d] Data estimated.
[e] Ditch and flume.
[f] See special description of the Miocene ditch (pp. 123–126).
[g] 1901.

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TABLE 8.—*Water conduits in Alaska and the North*—Continued.

| Locality. | Flumes. | | | | | | | | | | | | | Notes. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Length. | Grade in feet per mile. | Width. | Depth. | Size of boards. | Size of posts and sills. | Size of stringers. | Average amount of water used, miner's inches (1.5 cu. ft. per min.). | Greatest head. | Cost of construction per mile. | Annual cost maintenance per mile. | Cost of lumber per M. | Average open season. | |
| Council district: | | | | | | | | | | | | | | |
| Ophir Creek | | | *Ft. in.* | *Ft. in.* | *Inches.* | *Inches.* | | | *Feet.* | | | | | |
| Do | 900 feet | 6.60 | 5 8 | 4 0 | 1½ by 12 | 4 by 6 | | 3,300 | 200 | $20,000 | | $80.00 | June 10–Oct. 10 | There are completed or under construction in Ophir Creek, 55 miles of ditches. |
| Do | | | | | | | | | | | | | do | |
| Do | | | | | | | | | | | | | do | |
| Do | 1,000 feet | 6.60 | 4 0 | 2 4 | 1½ by 12 | 2 by 4, 6 flat | 8 by 8 inches by 12 feet. | 1,500 | 100 | | | 80.00 | do | 20 piers and trestles, pier cribs rock filled. |
| Do | | | | | | | | | | | | | | |
| Gold Bottom | | | | | | | | | | | | | June 10–Oct. 10 | |
| Solomon district: | | | | | | | | | | | | | | |
| Solomon River | | | | | | | | | | | | | June 25–Oct. 10 | |
| Do | 1,000 feet | 8.00 | 10 0 | 3 0 | 1 by 12 | 4 by 4, 4 by 4 | | 1,200 | 120 | | | | do | |
| Port Clarence district: | | | | | | | | | | | | | | |
| Sunset Creek[b] | | | | | | | | | | | | | June 15–Oct. 1 | |
| Klondike River | 2,600 feet | 2.22 | 2 6 | 2 6 | 1½ by 12 | 4 by 4, 4 by 4 | 4 by 6 | 500 | | 6,000 | | 50.00 | | Estimated capacity, 1,000 miner's inches. |

[a] Data estimated.

[b] Not visited.

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Long conduits are used in order that the difference in elevation between the source of the water and the point where it is used may afford the pressure. The length of the conduit will depend on the slope or grade of the surface. In regions of low mountains and gentle slopes, long ditches or flume lines are necessary. In steep mountain regions the same results are attainable with short conduits.

In the gravel-mining districts of Alaska examples of the two extremes are found. It is an unfortunate, but at the same time natural, result of the governing geological conditions, that to obtain the use of water under head ditches must be the largest in the richest and most promising placer districts of Alaska. A long head ditch is expensive both to construct and to maintain. That the expense of such undertakings has not deterred miners from attempting them is evidenced by early California operators, where single companies sometimes built more than 100 miles of ditch line. Each mile of ditch line or other form of conduit adds from $2,000 to $15,000 to the initial capital necessary to start the hydraulicking operation, and increases the annual cost of ditch maintenance.

Some of the precautions which apply equally well to any country regarding the construction of water conduits, found in the text-books on hydraulic mining, may well be repeated here.

Van Wagenen[a] says:

When the miner has measured the stream from which he is to draw his water supply, and has determined the point where he will tap it, he is prepared to consider the question of water channels. These may be of three kinds—the ditch, the wooden flume, and the iron pipe. * * * It is generally desirable to have the least possible fall in a water channel, or, in other words, to bring the water to as high a point of the ground to be worked as circumstances will allow. As the friction of the sides and bottom of a channel retards the flow, and necessitates a higher grade than would be necessary if there were none, it becomes of importance to decrease this element as much as possible. On this score wood and iron waterways present decided advantages, owing to their comparative smoothness. In any case, however, the quantity of friction developed depends upon the wet perimeter of the channel used. The following law will therefore be found to be of service:

*The least wet perimeter that will hold or carry a given volume is attained when the width of bottom is from one and three-fourths to two and one-fourth times the depth of the sides.*

For example, a channel having a cross section of 510 square inches will develop the least amount of friction when its dimensions are 15 by 34 or 17 by 30, or somewhere between these measurements. A knowledge of this fact will be found serviceable in constructing flumes. The least perimeter, of course, requires the least lumber, and many thousand or million feet may be saved in a long flume by building in the correct proportions.

Bowie[b] says:

All water courses on the line of the ditch should be secured. Their supply partially counteracts the loss by evaporation, leakage, and absorption, and frequently furnishes an additional quantum of water during several months of the year.

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[a] Van Wagenen, T. F., Manual of Hydraulic Mining, 1880, p. 51.

[b] Bowie, A. J., Jr., A Practical Treatise on Hydraulic Mining in California, 1885, p. 135.

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At proper intervals waste gates should be arranged, so as to discharge the water when necessary without risk of damage to the ditch. In regions of heavy snow these wasteways should be provided at intervals not greater than one-half mile. * * * Ditches poorly built in the beginning subsequently require large and constant expenditure, and lose considerable amounts of water

George H. Evans[a] says:

At the different points along the line of race where fluming has to be resorted to, allowance should be made for an increase in grade, in order that the flume can be constructed of much smaller dimensions than the ditch and yet carry all the water required. * * * It will be well to remember that practical results have demonstrated that in ordinary ground the water should travel at the rate of from 180 to 200 feet per minute. Then the grade will be determined by the dimensions of the ditch and its intended carrying capacity.

The above quotations may be considered as of general application, but many modifications in the hitherto accepted practice of ditch building have been found advisable in Alaska, and will be referred to, especially in the description of the practice in Seward Peninsula. Regarding the capacity of open conduits, Bowie makes the following statement:

In the mining districts of California ditches are constructed badly, with steep grades and on irregular lines with numerous sharp curves. The cross sections, originally uniform, became more or less varied. Absorption, percolation, evaporation, and leakage reduce the flow. A distinct, reliable factor for each of the sources of loss can not well be incorporated in the coefficient of discharge. * * * The simple formula $Q=ac\sqrt{rs}$ expresses more fitly the result of experience in such cases, wherein:

Q is the quantity of water which the ditch is capable of carrying in cubic feet per second.

$a$, the effective area of cross section of ditch, as originally constructed, in square feet.

$r$, the hydraulic mean depth in feet.

$s$, the fall of surface in a unity of length.

$c$, a coefficient covering all common losses.

Statistics derived from experience on the Milton, La Granger, and Bloomfield ditches in California led to the adoption of values of the coefficient $c$ varying from 31 to 45, in estimating the capacity of ditches in heavy grades of 40 miles' length flowing from 60 to 80 cubic feet per second.

The Texas Creek branch ditch (of the North Bloomfield ditch) is about seven-tenths of a mile long. Its sectional area is 13.5 feet and the grade is 20 feet per mile. The sides are rough and the curves sharp. With a flow of 32.8 cubic feet per second, the ditch runs about full. The value of $c=33$. In connection with this ditch there is a rectangular flume 2.67 feet wide by 2.83 feet deep, made of unplaned boards, set on a grade of 32 feet per mile. The flume has some sharp but regular curves, and the water from the ditch runs nearly full at these points. With the discharge 32.8 cubic feet per second, $c=59$.

Although the losses in leading water in Alaska have not been determined by exact experiments, it is likely that they are less than in California. In the interior the value of $c$ for ditches would be slightly

[a] Evans, G. H., Practical Notes on Hydraulic Mining, San Francisco, 1898.

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higher than in California, while in the ditches made on gentle slopes in Seward Peninsula *c* would be considerably higher. Its value can not be known until accurate experiments have been conducted on the various ditch lines.

Examples of the discharge of ditches in California, given by Bowie, are as follows:[a]

| Locality. | Length. | Grade. | Size. | Discharge. |
|---|---|---|---|---|
| | *Miles.* | | | *Miner's inches.* |
| North Bloomfield ... | 55 | 16 feet per mile .... | 8.65 feet top by 5 feet bottom by 3½ feet deep. | 3,200 |
| Dutch Flat ..... | 13 | 13½ feet per mile ... | 6½ feet top by 4 feet deep. | 3,150 |
| La Grange..... | 20 | 7 to 8 feet per mile. | 9 feet top by 6 feet bottom by 4 feet deep. | 2,400 |

In considering ditches and ditch building, the three provinces of Alaska, namely, the South Coast, Interior, and Seward Peninsula, will be taken up in succession.

### SOUTH COAST PROVINCE.

In the South Coast province of Alaska the topography permits a rapid increase of head in short distances. (See Pl. XVI, *A*, p. 114.) The ditch line of the Alaska-Treadwell Gold Mining Company, 14 miles in length, delivers water from the penstocks above the mill—to which it supplies power—at an elevation of 480 feet. As may be seen from the map (fig. 19), the ditch heads in Fish Creek 1,000 feet above the sea. The water at the upper penstock, midway on the ditch between Douglas and Treadwell, is taken out at an elevation of 600 feet above the sea. The distance from the penstock to the nozzle is only 1,500 feet on slope, and it may easily be seen what advantage is gained from the steep topography. The grade of the mountain, nearly 30 feet in 100, is such that were a sufficient amount of water available in one of the near-by creeks no ditch at all would be required. The water could be led out by a few hundred feet of flume to a penstock, and a pipe line led directly from this to the mill. The Treadwell ditch line is composite, so far as its contained water is concerned, since it taps successively Fish, Eagle, Cowee, Lawson, Paris, Bullion, and Ready Bullion creeks. Its length is not extreme considering the amount of water obtained, but it is considerably greater than would have been necessary if all the water could have been obtained from a single creek or river.

[a] Bowie, op. cit., p. 139.



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The apparent extraordinary fall of the Treadwell ditch (over 20 feet to the mile) may be accounted for by the fact that it has, at each creek which it taps in its course, a drop off of 6 to 7 feet, and reservoir, in which are relief gates, as illustrated in the photograph of the ditch at Lawson Creek. (See Pl. XVI, *B*.) One of the waste gates shown on Pl. XVI, *B*, is 5 feet 4 inches wide; the other is 6 feet 7 inches wide and 3 feet 3 inches deep. There is a smaller auxiliary gate 4 feet 6 inches wide and 2 feet deep.

The Treadwell main ditch is 14 miles in length, and is supplemented by 4 miles of subsidiary ditches.[a] The main ditch heads in Fish Creek, and its supply of water is obtained successively from Eagle, Cowee, Lawson, and Paris creeks, while an additional ditch brings water

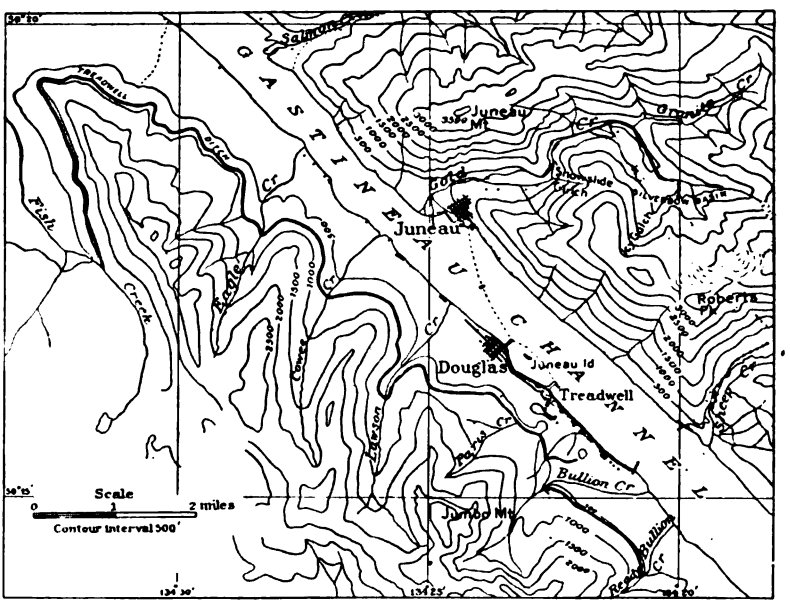



FIG. 19.—Map of portion of Juneau district.

from Ready Bullion and Bullion creeks. In summer the water is used for running 760 of the 880 stamps of the mills, but in winter it is not used for power purposes.[b]

The main ditch has a width of 7 feet on top and 6 feet on the bottom, and a depth of 5 feet. In 1904 construction was going on in portions of the ditch line as follows: Twelve-inch posts, in sets with 5-foot centers, were being placed along the inside of the ditch, leaving space 5 feet in the clear at bottom and 4½ feet in the clear at top, with 7-inch cap logs 4½ feet between shoulders. Lagging split 3 inches thick and 1½ feet wide was laid inside the posts. Moss and sod were

[a] See Kinzie, R. A., The Treadwell group of mines, Douglas Island, Alaska: Trans. Am. Inst. Min. Eng., vol. 34, 1904, p. 374.

[b] It is to be regretted that full data regarding the Treadwell ditch are not at hand.

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*A.* TOPOGRAPHY, SOUTH COAST PROVINCE.



*B.* TREADWELL DITCH LINE AT LAWSON CREEK, DOUGLAS ISLAND.

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then filled in between the lagging and the side of the ditch, poles laid lengthwise over the caps, and sod laid over the whole. Fluming has been found very unsatisfactory at the Treadwell. The flume was banked with sod on sides and top. Anchor ice in winter collected in the bottom of the flume, and was removed with great difficulty.

The Treadwell ditch for long distances is bridged with poles and brush, which in many places are covered with sods. Sodding is said to be the best preventive against freezing, not only here, but in all parts of Alaska.

The pressure boxes are connected with the ditch by flumes 35 feet long, 5 feet wide, and 3 feet deep. The water first enters a gravel tank which is cleaned twice a year. This tank is built of 2-inch lumber and is 8 feet wide by 9 feet long and 14 feet deep. From the tank the water flows through a 4-foot section of flume 3 feet 3 inches wide, the bottom of which is only 5 feet below the top of the tank, into the main penstock. This is 11 feet long by 9½ feet wide, inside measurement, and 14 feet deep. It is built of 3-inch lumber, with 8- by 10-inch posts, sills, and caps, with 4-foot centers. The penstock is fitted with a wooden inclined grizzly to catch any leaves or refuse that pass the gravel trap. The penstock and sand trap combined make a structure 20 feet 6 inches long by 10 feet 10 inches wide by 14 feet deep, outside measurement. The penstock, as illustrated in Pl. XVII, *A*, is banked halfway up the sides with sod, and the pipe line leading from it is covered with sod. The sand trap is provided with a sluicing-out gate on the side opposite that shown by the photograph.[a]

Pl. XVII, *B*, illustrates a method of guying the pressure box on steep slope, in use by the American Gold Mining Company in Silver Bow basin, Alaska. The intake of the pipe line is protected by shed from heavy snows.

As water is in use for placer mining only during the open season, few instances were seen in Alaska of attempts to sod up the ditches and connections to prevent freezing in winter. At the Treadwell, however, the water is used for generating power. Pipe lines, especially in Seward Peninsula, are frequently sodded over, as much for protection against rust as to prevent freezing.

In Silver Bow basin, east of Juneau, ditching has been found impracticable and all conduits are flumed. In general in southeastern Alaska fluming will be found cheaper than ditching, as ditches would have to be cut in solid rock for the most part, and in numerous places the mountain slopes are so steep as to render their construction impossible.

[a] See Bowie, A. J., jr., A Practical Treatise on Hydraulic Mining in California, 1885, p. 177, for plan and elevation of North Bloomfield pressure box.

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The flume of the Jualpa Company,[a] one-half mile northeast of Juneau, is shown on Pl. XVIII, *A*. The water is taken from Gold Creek, the head gate being 9 by 8 feet. The flume is 4,600 feet in length, and has a grade of 1¼ inches in 16 feet, or 34.3 feet to the mile. It is 4 feet 8 inches square, inside measure; the bottom and side boards are 2 inches thick, planed inside, and battened with 3- by ½-inch lumber; there are 4 collars to a box of 12 feet; each alternate collar consisting of a 5- by 5-inch sill, 8 feet long; two posts 4 by 6 inches by 5½ feet high, with a gain of one-half inch into sill, and two caps of 2- by 4-inch pieces nailed to the sides of the posts above the cover boards. The yokes are braced with 2 by 12's. These collars have 6-foot centers, and alternately between them are yokes consisting of a 3- by 5-inch sill, and two 4- by 4-inch posts, uncapped. The flume is covered with boards 1½ by 12 inches by 5 feet, laid crosswise, and nailed. Each box contains approximately 425 board feet of lumber. The cost of the flume is said to have been $2.20 per foot, or $11,616 per mile, including lumber and labor. This did not include the cost of shooting rock for the flumeway, which was as high as $5 per foot in places. A head of 225 feet is obtained, and the capacity of the flume is said to be 5,000 miner's inches.

The pressure box to which the flume leads is 12 by 18 feet by 11 feet deep. It is built of 1½-inch lumber, and has collars of 8- by 8-inch timber. The pipe at the intake end is 36 inches in diameter.

In building flumes about Juneau trestling frequently has to be resorted to, thus adding greatly to the expense. In general it may be said that the cost of building a 4-foot flume in the South Coast province will not fall greatly below $10,000 per mile, and will occasionally be double this amount.

For small flumes, Bowie gives the following specifications:[b]

*Specifications for flume 2½ feet wide, 2½ feet deep; 12-foot box.*

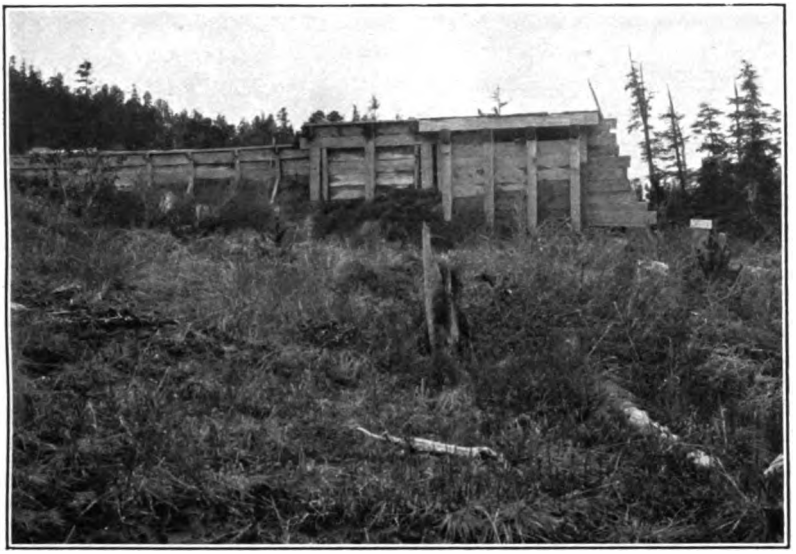
| | Feet. |
|---|---|
| 3 caps, 4 feet by 3 by 4 inches | 12½ |
| 6 posts, 3 feet by 3 by 4 inches | 18 |
| 9 planks, 12 feet by 1½ by 6 and 12 inches | 135 |
| 3 sills, 4½ feet by 4 by 4 inches | 18 |
| 2 stringers, 12 feet by 4 by 6 inches | 48 |
| 6 battens, 12 feet by 3 inches by 1 inch | 14 |
| 1-foot plank, 12 feet by 10 by 1½ inches | 15 |
| Total lumber in one box | 264½ |

Number of boxes per mile, 440.

[a] Recent information (Mining and Scientific Press, December 31, 1904), states that elaborate preparations for operating this property were made the last summer. These include the interception of the water of Gold Creek above the property by a dam, and its diversion to a flume to carry it past the hydraulic pit. The flume is 20 feet wide by 9 feet deep, and 4,250 feet long, 2,250 feet being trestled. It contains 1,200,000 feet of lumber, 6,000 linear feet of hewed timber, and 20 tons of nails and bolts.

[b] Op. cit., p. 119.

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*A.* PRESSURE BOX IN TREADWELL DITCH.



*B.* METHOD OF STAYING-PRESSURE BOX, SILVER BOW BASIN.

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Reckoning the cost of lumber for a box at $4 and the labor of 1 man at $5 for one day to each box, such a flume would cost $4,000 per mile, exclusive of survey, rock work, and trestles. It is difficult to see how the cost of building even small flumes can fall below $7,000 per mile in the South Coast province of Alaska.

### INTERIOR.

In the interior Yukon and Tanana fields ditching is practicable and is recommended in preference to flumes. There are difficulties, but they are not insurmountable. In the interior no large ditch enterprise similar to those of Seward Peninsula has been undertaken. The Atlin field has afforded data regarding building of ditches, but conditions are hardly comparable with those in the Yukon region. With the exception of the small amount of bench mining in the interior only a small amount of gravel is handled daily, and ordinarily water under very low heads is used.

The future of hydraulic mining in the Klondike, Birch Creek, Fortymile, Eagle, and Tanana mining districts is not promising. The gentle slopes of the mountains, the low grade of the creek valleys, and the sparse amount of water are unfavorable to obtaining a sufficient amount of water for hydraulicking at a working head. A peculiar drawback, depending on the geological history of the region, is the fact that the level tops of the Yukon and Tanana mountains represent a partially eroded peneplain of very wide extent—300 miles from east to west and 200 from north to south, approximately. This area, in which the placer fields of the Yukon-Tanana rectangle are situated, is, as it were, a table-land, the top of which tilts slightly to the south, and into which the modern streams have cut, rounding off the residual parts between them into low dome-shaped mountains, averaging 3,000 feet in height, and varying from 6,000 to 2,000 feet.

A comparison of the topography of the South Coast province with that of the interior is illustrated by Pls. XVIII, *B*, and XIX, *A*. In the interior there are no sharp declivities, no waterfalls, no sudden descents in the surface. The grades of creek valleys are seldom over 3 feet in 100 and are commonly 1 foot in 100. (See table 8, p. 104.) If 2 per cent is taken as an average grade and it is assumed that a ditch must be three times as long as the creek on which it is to furnish water under head at a lower point, it is evident that only 300 feet head would be obtained by 10 miles of ditch. Such a ditch taken from one stream would afford only 200 miner's inches of water, a fair average for the region during the four months of the summer season.

Within leading distance there are no high mountains from which to draw a supply. The alpine peaks of the Alaska Range lie to the south of the Tanana, and could not by any possibility be made to afford water to be used for hydraulicking. (See Pl. XLI, *B*.)

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Ditches and flumes for conveying water must, as hitherto, be of small size. They will deliver a small amount of water at a low head, 100 miner's inches of water at 75-foot head being about what may be obtained under favorable conditions.

Special difficulties encountered in the interior of Alaska and the North generally have been found to be as follows:

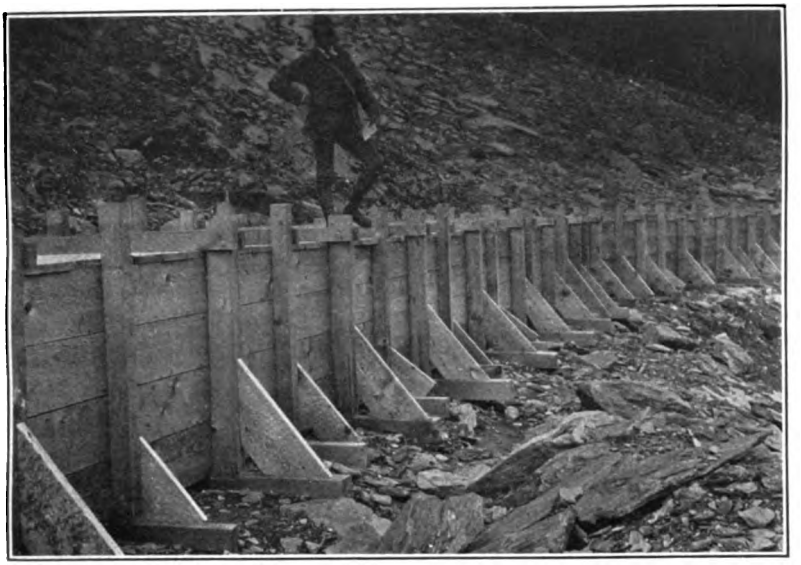
At Atlin the action of frost causes the ditch to enlarge after construction. The opinion was expressed that steel-pipe conduits do not freeze as quickly as flumes. In a 19- by 40-inch flume of 1,960 feet in length it was found that the frost heaved the flume and put it out of grade each season, but even then it was regarded as more economical than a ditch. The flumes on McKee Creek have to be gone over every spring to restore the grade. Sills are set in 4 inches of blocking on the stringers so that the grade can be regulated. It was also said that the native Atlin lumber is preferred for the flumes and sluices, as imported Pacific coast lumber warped badly. If native lumber is used, 8 inches is the greatest width available. Notwithstanding the cost of maintenance, ditches are much used at Atlin, one company operating 10 miles of ditch.

In the Klondike district, where nearly all ground is solidly and permanently frozen, it is said that three years after construction must be allowed to get a ditch into condition to stand. Various estimates have been made and projects formulated in this field for bringing in water from a distance for the purpose of working the remaining gravels of the benches (the so-called "White Channel") which lie at an average elevation of 270 feet above the rich bottoms of Bonanza, Eldorado, and Hunker creeks. The building and maintenance of a ditch having its source in some of the higher tributaries of Klondike River and affording water at a sufficient head is not regarded as an impossible engineering feat, but up to the present the cost has been considered prohibitive. Dry seasons alternate with wet ones, and in consequence the amount of water available during a given season might vary from, say, 1,000 inches to 5,000 inches. No calculations based on the full capacity of the ditch could be made in advance, therefore, regarding the season's product.

Recent information concerning the Acklen ditch, led along the north side of Klondike River near Dawson for the purpose of hydraulicking high benches bordering that stream, has been embodied in the table. It is stated that the cost of the earth excavation of this ditch, 7 by 4 by 2½ feet deep and 41,500 feet in length, was $34,000.

Small storage reservoirs are used by many of the Klondike operators to impound the small and variable amount of water available for working the benches of the White Channel. On Hunker Creek a small ditch 3 by 2 feet and 4 miles long is in excellent condition after

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*A.* FLUME OF JUALPA MINING COMPANY, SILVER BOW BASIN.



*B.* TYPICAL SOUTH COAST TOPOGRAPHY, GOLD CREEK.

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four years' service. The annual cost of maintenance is $1,000, or 10 per cent of the original cost.

In ditching in bad ground it has been found beneficial not to remove the moss carpet, but to cut it in 4-foot lengths, transverse to the line of ditch, then to roll it back along the lower edge, and after the ditch is dug to let it drop so as to cover the side of the ditch.

In the region adjacent to Eagle, Alaska, it has been found that where the topography did not admit of ditching the maintenance of flumes is very expensive and that the use of steel-pipe conduits is preferable.

A useful suggestion for flume building was obtained on Deadwood Creek, in the Birch Creek district. Flat timbers obtained in the neighborhood were used, and the flume, 3 feet by 1 foot, was calked with moss inside. The cost was only 25 cents a foot, and the flume is said to be good for ten years. In this locality it is almost impossible to secure sawed lumber at any price unless the operators whipsaw it themselves. In all northern latitudes the moss is an excellent calking material.

Through the interior country it has been found that ditches on the south slopes of the mountains can be made with much more success than on the north slopes. In fact, the north slopes are frequently bare rock, while on the south slopes a good deposit of earth has accumulated.

The presence of crystosphenes,[a] which are found on the slopes as well as in the creek valleys in all parts of the north where perpetual frost prevails, is the ditch maker's greatest obstacle. Mr. Tyrrell says: "As a rule they [the crystosphenes, or so-called 'glaciers'] occur as more or less horizontal sheets of clear ice, from 6 inches to 3 feet in thickness, lying between layers of 'muck' or fine alluvium, usually where the 'muck' is divided horizontally by a thin bed of silt or sand; and most of them, as far as my observation goes, are from 2 to 4 feet below the surface, though some are deeper. They approximate closely to the slope of the surface, under which they lie." These sheets are from 25 to 150 feet in diameter, generally somewhat oblong. They are explained by Mr. Tyrrell as due to the freezing of seepage water, causing a gradual accretion to the mass annually. Mr. I. P. Tolmachof[b] has examined similar occurrences in northeast Siberia, and explains them as fossil snowbanks. Whatever their explanation, they are exceedingly common both in the interior and in Seward Peninsula. They are found not only in creek beds, but on the slopes, and show no regularity in distribution.

[a] Tyrrell, J. B., Crystosphenes, or buried sheets of ice, in the tundra of northern America: Jour. Geol., vol. 12, 1904.

[b] Ground ice of Berezovka River: Proc. R. Russ. Min. Soc., St. Petersburg, 1903.

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Where such a mass of ice is met sod and moss must be extensively used, and both the first construction and annual maintenance will be much greater than in other portions of the ditch. For an account of the method of dealing with such ice sheets see the description of ditch building in Seward Peninsula.

In the Fairbanks district so little ditching has been done that no results gained from experience were available. The frozen ground has, however, been found so bad for ditching that the cost of annual maintenance is from one-fourth to one-half as much as the first cost of construction. Such expedients as patching with canvas have been adopted as a temporary makeshift. The small ditches which have been constructed are run with as flat a grade as possible to avoid cutting out. Here as elsewhere in the interior the use of sod for lining the sides of the ditches can not be too highly recommended.

Small reservoirs in the creek beds for impounding sluice water are in use and will be described in connection with open-cut mining.

### SEWARD PENINSULA.

The following notes regarding the building of ditches have been contributed by Mr. Guy A. R. Lewington, of Nome, Alaska, manager of the mining properties belonging to the North American Transportation and Trading Company:

Ditch building in Seward Peninsula has become one of the most serious questions with reference to economical mining and the general stability of the whole mining industry. Water under pressure for hydraulic mining is the all-important condition, and to this end I submit the following, which may be of some interest to those contemplating investment in this section.

The necessary equipment consists of plows, scrapers, and graders of the usual kind in use in the States, and, of course, a camp outfit of tents, both for living and stable purposes.

The conditions to be contended with in this country are different in almost all respects from those which have come under my observation elsewhere. The most serious of these is the building of a tight and strong ditch over "glacier,"[a] of which much is encountered wherever ditches have been constructed. Under this condition it has been found best to dig as shallow and broad a ditch as possible, not digging much below the moss, and to build the outer bank of the ditch up to the required height by the use of the sod which covers the whole country. This sod in a short while settles and knits itself together, and thus becomes a very serviceable bank. It will not cut or wear out, and the older it gets the better it becomes. When, however, it becomes evident that the bottom of the ditch is cutting and wearing away, sod again must be resorted to, and by lining the bottom of the ditch with it the trouble may soon be overcome. In this way a ditch can be made over perpetually frozen ground where otherwise it would be impossible. Much ditch has to be constructed over loose stones with little or no sediment between them. In this case the ditch must be lined with sod and all holes must be filled by tamping sod into them as far as possible. This being done it will be found that the water traveling through the

[a] The buried ice sheets.

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*A.* TYPICAL INTERIOR TOPOGRAPHY, MASTODON CREEK, BIRCH CREEK DISTRICT.



*B.* DITCH BUILDING, HEAD OF NOME RIVER, SEWARD PENINSULA.

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ditch will deposit sediment over the sod and level it up, and that after a little while it will become tight. Puddling, of course, will help any ditch here or elsewhere. Those two conditions are the only serious ones to be contended with in ditching ground.

A strong plow drawn by 2-horse team is the first implement used. (See Pl. XIX, *B*, p. 120.)

All being ready, the driver is instructed to plow a single furrow, following as closely as possible from one survey peg to the next, following the natural contour of the country. This he does for say a distance of one-half mile, thus establishing the ditch line. The plowing is continued to a width sufficient so that, allowing plenty of slope for the inner bank, the required depth of ditch may be obtained. The grader is next used for the purpose of removing what has been plowed to the outer bank of the ditch. This being done the ditch will look much like a wagon road. Then the plow is used again, plowing as before a single furrow, following as nearly as possible the first furrow plowed, which is plainly visible. This second plowing being done, the scraper is resorted to, and the loose plowed material is scraped from the ditch to the outer bank, building it up. This work is repeated until the ditch is almost completed. All that remains to make an excellent ditch is to level up the bottom and to slope the ditch to required dimensions. This work is done by hand with pick and shovel. The plow and scraper should do almost all the work, however, so that as little as possible remains to be done by hand. After completion of the ditch only a small head of water should be allowed to flow through it for a few days, until it has become well soaked; then the head may be gradually increased a little daily until the full capacity is reached.

All water should be turned out of the ditch before the freeze-up in the fall, and the ditch made as dry as possible by the opening of all waste gates, of which there should be one at least every one-third of a mile. These waste gates should be left open, to enable the water during the spring thaw to run out of them instead of filling the ditch with water and overflowing its banks. These waste gates should be cleared of all snow and ice at the first approach of a thaw in the spring, in order that the water may have a free outlet. This is very important. In the spring no water should be allowed to run through the ditch until at least 2 to 3 inches in depth of the ditch has thawed, and then only a small head to start with, as frozen ground cuts very rapidly. If this work is carefully done I have no doubt that the ditch will be ready for work by the time it becomes possible to mine.

Considering the remoteness of the country and its high latitude, ditch building can be done at a cost surprisingly low. The entire absence of timber, small amount of rock work, generally good soil, and gentle slopes of the hillsides are conditions which make ditch building very feasible in the auriferous portions of Seward Peninsula.

Fluming should not be employed unless absolutely unavoidable, as frost and snow in winter play havoc with flumes, and the swelling and contracting of the ground, due to alternate freezing and thawing, continually keep the flume off grade. There are few instances where it is necessary to use a flume.

Much of the ditch construction at Nome is now done by contract. The following information was supplied for this report by one of the ditch contractors at Nome:

In the construction of ditches on Seward Peninsula the following three types of machines are used, all being drawn by horses: The ordinary road grader, the horse scrapers, which are so extensively used in California, and an ordinary breaking plow.

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After the ditch line has been surveyed and staked 30 men and 20 horses, for example, with plows and scrapers, are put to work. The plows proceed ahead of the grader, and the cutting is continued until the uphill side of the ditch bottom is nearly cut to grade. At this stage, which is represented ideally by fig. 20, it will be seen that the contents of the cut A, B, C has been thrown up to form the bank C, D, E on the outer side of the proposed ditch. The remaining work consists in removing the earth in the portion B, F, H, which is partially uncut and partially built up by the grader. The most economical work is done when the portion removed by the grader is so balanced as to demand the least cutting by the scrapers in throwing up the necessary bank. It will be seen from the above statements that the burden of the work falls on the first plows and on the grader, though the subsequent work of the scrapers and hand finishing is just as important.

Four horses and 1 man are usually used to a grader, though 8 horses are often used. The scrapers use from 2 to 4 horses, depending upon

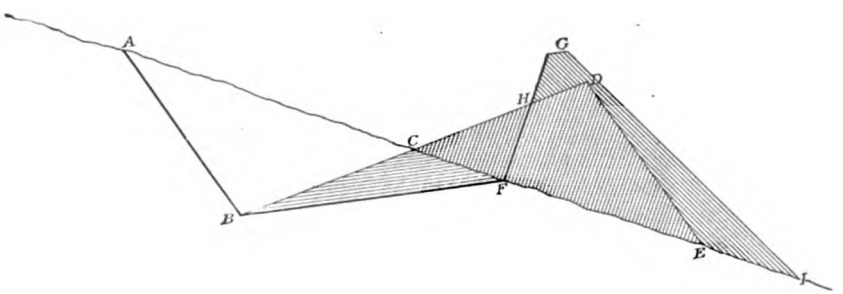



FIG. 20.—Section of ditch in construction.

the size of the ditch. Four horses are not generally used to a scraper unless the ditch is to be 7 feet or more wide. The plows breaking first ground usually need 4 horses each. It may be said that where a slope is steep very little or no cutting is needed on the lower side of the ditch, since the dirt necessary for the bank can all be obtained in reducing the upper side to grade.

Special methods are necessary when the ditch passes through sections underlain by ground ice, as previously described, or runs over sections of rock. Very careful work is needed when the rock is broken and fractured. It has been found bad practice to cut through the stringy moss which overlies the masses of ground ice, generally referred to as "glacier;" in fact it is disastrous to the permanency of that section of the ditch, and is the beginning of never-ending repairs, since the ice continues to thaw, causing constant leakage. The best practice is to build sod walls on the lower side, leaving the moss undisturbed. All rock work must be done by hand, and where the ditch

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passes through fractured material all cracks must be filled with moss. Too much care can not be observed in the latter detail, and, especially during the first weeks of use, men must be kept constantly traversing and repairing those sections where leaks are apt to occur. The stirring up of the water by men walking along the bottom of the ditch is a good practice in the early stages, for silt, in addition to the sod, is a most valuable factor in filling the cracks.

A scraper will work to great advantage in decayed schist, which needs no lining, as it holds water better than any other ground encountered and cuts out less. Fluming does not pay when there is a possibility of ditch building. In fact, it has been often stated by men familiar with ditch construction, that where possible, it is profitable both as regards first cost and subsequent maintenance to build a ditch in place of fluming, even if the distance necessary to be covered by the former be ten times that of the latter. Many slopes apparently not permitting a ditch cut, owing to the presence of broken rock and talus slides, on close examination are found to be favorable, for if 2 or 3 feet of this loose material is moved there are excellent opportunities for comparatively cheap rock cuts.

When, however, it is deemed impracticable to construct a ditch, and where a flume must be built crossing a gully, a very efficient foundation can be made by digging shallow holes, filling with gravel, and placing on top a wide plank to distribute the load. If the trestle rests on such foundations, and the underlying ice is not disturbed, much trouble from settling will be avoided. The following are a few of the costs representative of ditching in various materials:

*Cost of ditching in various materials.*

| | |
|---|---|
| Soft muck and tundra, per cubic yard | $0.75 |
| Gravelly dirt, per cubic yard | .65 |
| Decayed schist, per cubic yard | .40 to .60 |
| Rock work, fairly solid, per foot | 1.75 |
| Schist in place, per cubic yard | 1.00 |
| Loose rock, per cubic yard | 1.25 |

Ditching in muck which heaves is very expensive, and no general figure can be given.

A ditch carrying 1,000 miner's inches will cost, under fair conditions, $2,000 per mile. One with the capacity of 4,000 miner's inches will cost between $4,000 and $5,000 per mile. Though much affected by varying local conditions a conservative estimate for general work is $1 per cubic yard throughout.

The following account of the construction of the extensive water conduits built by the Miocene Ditch Company was obtained from Mr. J. W. Davidson, the company's consulting engineer.

The water is taken from Nome River and its tributaries for the most part, although a small portion is taken from Snake River. At the

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intake near the head of Nome River the elevation is 572 feet.[a] At Hobson Creek a large head dam has been constructed entirely of sod. The dam was started at bed rock and is 20 feet in width by 130 feet in length and is provided with a waste gate 10 feet wide and 10 feet deep in the center. It has been found entirely satisfactory. The ditch, with its branches and laterals, is 54 miles in length. Of this, the main ditch is 31½ miles from Hobson Creek to the tunnel. This ditch, as far as the "X," was made 10 feet on the bottom, 14 feet on top, with a depth of 3 feet. It has a grade of 3.37 feet to the mile. Seventeen miles of ditch were made from the head of Nome River to Hobson Creek, with the dimensions 8 feet wide on the bottom, 11 feet on the top, and 3 feet in depth, with a grade of 4.5 feet to the mile. From the "X" to the tunnel, as represented on the map, the ditch has the same dimensions as the upper end, and a grade of 6.5 feet to the mile. The ditch was constructed to carry 3,000 miner's inches of water below Hobson Creek, and at the upper end to carry 2,500 miner's inches. The actual amount of water available under average conditions is said to be 2,000 inches. The ditch was begun on July 6, 1901, at the "X." (See fig. 21.) The following year 75 horses and the necessary equipment—

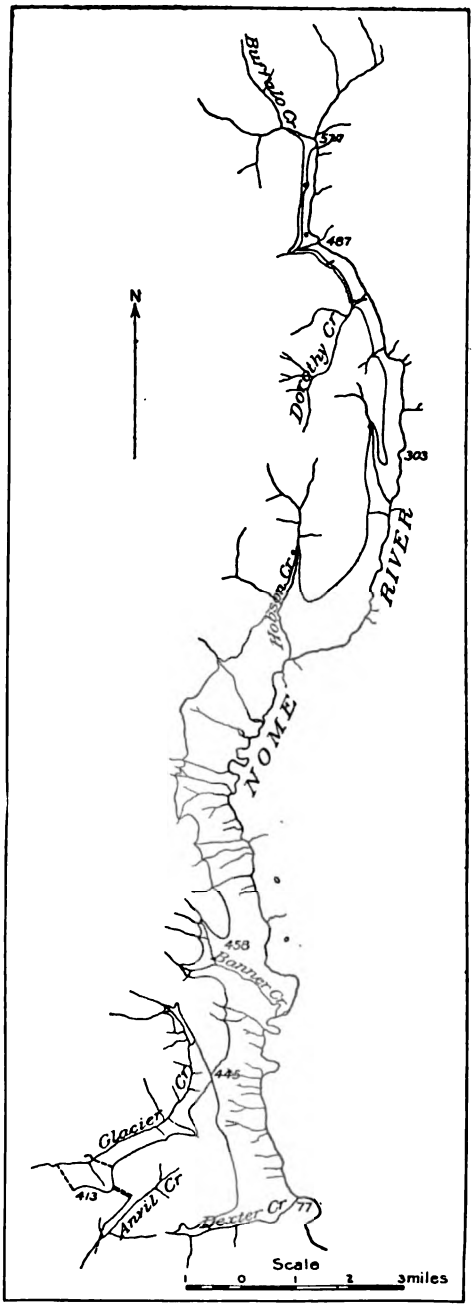


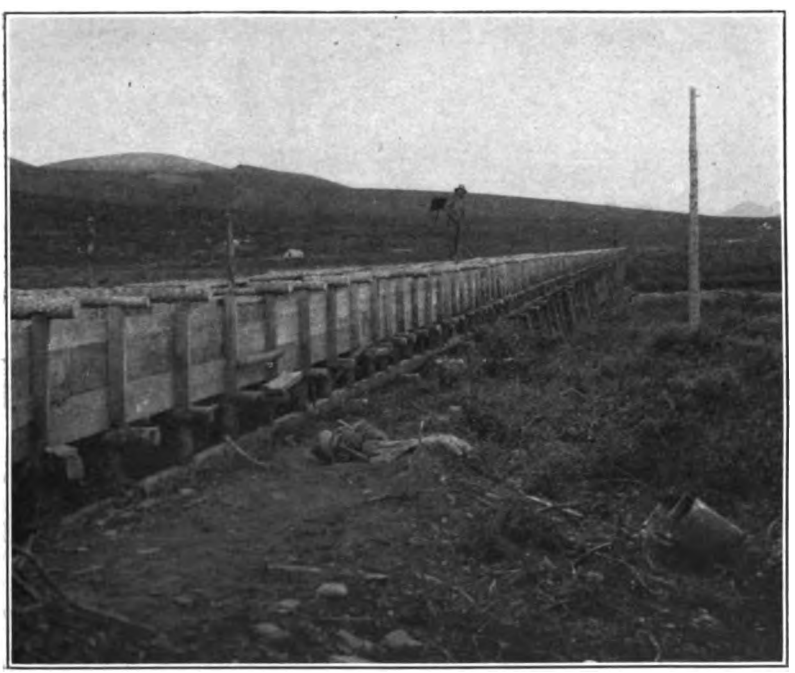

FIG. 21.—Map of Miocene ditch.

[a] According to levels by U. S. Geol. Survey.

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*A.* MIOCENE DITCH, GLACIER CREEK.



*B.* FLUME OF HOT AIR COMPANY, OPHIR CREEK.

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plows, graders, and scrapers—were brought in and the ditch was completed to Hobson Creek. In 1903 the ditch was completed to the head of Nome River and a branch ditch was constructed to tap Snake River. Sixty-eight days were consumed in building the ditch from Hobson Creek to Dexter Creek, forty-eight days from Hobson Creek to Nome River. This latter figure includes the enlargement of the originally built Hobson ditch and the building of the Snake River ditch.

The method of construction has been described above. A plow was used for breaking the furrows and the grader was used for bringing the cut to grade, 4 horses being used to a team. The ditch making was carried on at the rate of one-half mile per day, taking the triangular section off down to a level. This operation was followed by a second plowing. The grade stakes were set at a certain distance down the hill from the lower bank, and the men were directed to push the dirt so as not to reach beyond the line of stakes. From 60 to 70 men were employed all the time, and the number of horses varied from 50 to 100. The cost was reckoned at $400 for each horse for a period of eight months, and the wage of a man was reckoned at $7.50 per day. Two 4-horse teams were employed all the time to haul feed. (See Pl. XX, *A*.)

The grading gang consisted of one 4-horse breaking plow and a grader, with 2 men and 8 horses. A scraping gang consisted of 2 plows and 9 scrapers. There are thus 11 drivers, 2 men plowing with 2-horse plows, 9 scraper men, and a foreman, beside the grader. The general cost of the smaller ditch is given at $2,300 per mile. It is to be noted that in this construction the upper bank was not sloped at all, as it was found that this sloping is very little use in the northern regions, the soil standing very well at various angles.

The difficulties with ground ice were very great. At one place 800 feet of such an ice sheet was found, and here the cost of maintenance is exceedingly high. The only way to maintain the ditch is to haul clay down the ditch in boats and dump it in. It is found that if sufficient clay is dumped on top of the ice it stops thawing, but this operation has to be annually repeated. At another point 1,100 feet of flume (8 feet by 33 inches, with double grade) were built over an ice sheet, and so far the ground has settled very little. One and one-half inch lumber is used in construction, at a cost of $200 per thousand feet. For each mud sill cuts were made into the ice from 2½ to 3 feet. After the sills were in position the moss and tundra were rammed back over the ice. The cost of construction of this flume was $1,500, exclusive of the lumber. It is stated that the construction cost much more than it would at present.

At another point, across Manila Creek, an inverted siphon 1,000 feet in length, of hydraulic riveted steel pipe, 40 inches in diameter, 14 gage, is used for 1,000 feet, at a cost of $10,000. It has a dip of

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150 feet in the center, and the difference between the ends is 4 feet vertically. The allowance for friction made in this siphon was for 3,000 miner's inches of water. At the upper end the water discharges from a penstock 12 by 12 by 14 feet. Another inverted siphon line 300 feet in length, of 24-inch, 14-gage, riveted steel pipe, is laid across Dorothy Creek.

Around Cape Horn there was a considerable stretch of rock work, 1,300 feet in marble. This had to be blasted with powder, and cost $12,000. There are 5 miles of rock work in all along the ditch line. Between Snow Gulch and Glacier Creek a tunnel 1,800 feet in length has been run through the divide to carry the ditch water. Its dimensions are 4 by 6 feet, and it is timbered in places. The top of the tunnel is level with the top of the water on the entrance side, the bottom of the tunnel being run at a low level so as to completely fill the tunnel. All the rock work in the tunnel was done by hand drilling, and in the winter. The rock was found to be frozen 90 feet vertically below the surface. The elevation of the penstock for "No. 1 Below Discovery," Glacier Creek, where the bulk of the water was used in 1904, is 413 feet, the surface of the water being about 2 feet lower, the available head at No. 1, below Glacier, being 330 feet. The greatest head of water attainable by this ditch on ground now being worked is said to be 360 feet on No. 2, below Glacier Creek.

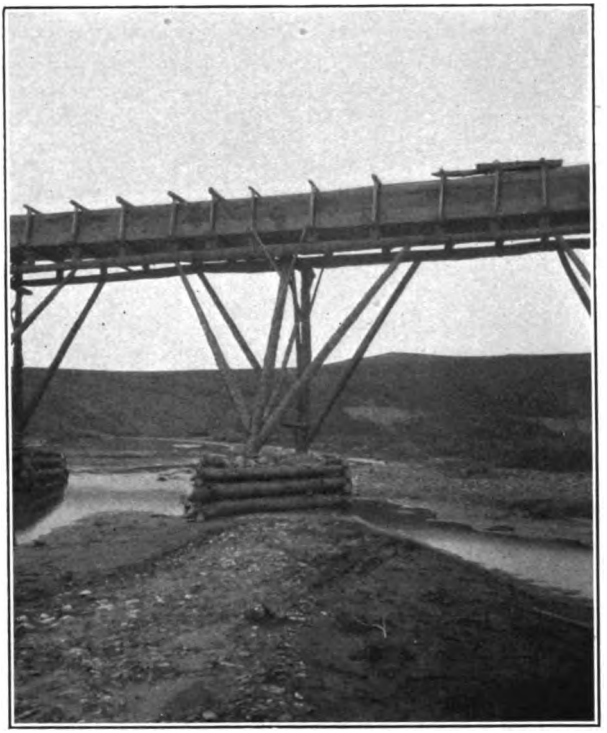
The complete cost of the ditch and all accessories, including maintenance for four years, is stated to be upward of $300,000. It is the practice to keep 15 men on the whole length of the ditch system during the four months of the working season. This company, besides the use which it makes of the water for its own mining operations, sells some of its water to the miners on Glacier, Anvil, and Dexter creeks at the rate of $1 per miner's inch under pressure, and at 50 cents per inch for water that has been once used.[a] According to measurements made with a Price current meter August 23, 1904, the Miocene ditch afforded 1,074 miner's inches above the No. 1, below penstock on Glacier Creek, and 1,752 miner's inches at a point on Glacier Creek above the tunnel leading a portion of the water to Anvil Creek, the inch equal to 1.5 cubic feet per minute.

In the whole of Seward Peninsula there are approximately 175 miles of water conduits, for the most part ditches actually constructed, and fully 100 miles more are reported as under construction or in contemplation. It is safe to say that the work has averaged in cost over $4,000 to the mile, although it is undeniable that with the advantage of experience the operators can build their ditches for less money in future.

Ophir Creek, in the Council district, has been the scene of the greatest activity in ditch construction, as may be seen by the table. There

[a] The miner's inch in this case is reckoned as equivalent to 1.2 cubic feet per minute.

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*A* PIER FOR TRESTLE, HOT AIR DITCH LINE, OPHIR CREEK.



*B.* SMALL STORAGE DAM, BONANZA CREEK, KLONDIKE.

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is estimated to be a total of 55 miles of ditches in this basin, including the ditch which taps Pargon River, across the divide. The largest ditch on this creek carries from 1,200 to 3,000 miner's inches, and is through rock and earth for over 18 miles. It was commenced in August, 1901, and work has been done on it at intervals up to the beginning of the season of 1904. It is estimated by the Wild Goose Mining and Trading Company that on Ophir Creek, in ordinary ground, a mile of ditch a week of this size, 16 by 10 by 3 feet, can be built with 32 head of horses and 70 men. In the 5 miles of rock work which were made along the line black powder was used for blasting. The sod walls were found preferable to rock walls in this ditch, as in the one built by the Miocene Company. The water is used for working several claims, a portion being distributed to each; the head attained varies from 170 to 200 feet in the different operations.

In the construction of the Hot Air Company's ditch line on Ophir Creek several long trestles (see Pl. XX, *B*) were found necessary where the ditch crossed and recrossed the many meanders of the creek. It was necessary to sink the posts of the trestling in rock-filled cribs or piers in the creek bed, as shown in Pl. XXI, *A*.

The use of inverted siphons is common in many of the Alaska ditch lines, but presents nothing new over the California practice. The ordinary rules to be observed in conducting water under pressure in pipes, the use of large-diameter pipe to prevent excessive friction, the calculation of the pressure, resistance, the loss of head, and the distribution of air valves are as important as in the case of all pipe lines.

## STORAGE RESERVOIRS.

Lack of water and of sites at a sufficient elevation to afford head render the building of extensive storage reservoirs in Alaska impracticable. The broad, flat valleys, frozen soil, impervious schist bed rock, and the excellent sod material for dams offer conditions which appear attractive. On the other hand, the small and variable amount of rain and snow (see table 2, p. 48) makes it certain that the expensive surveys and construction necessary for reservoirs whose capacity runs into the millions of cubic feet would never be justified by results.

Small storage reservoirs have been successfully built and have given satisfactory results. The capacity of one built by the Anglo-Klondike Mining Company is 400,000 cubic feet, or sufficient to supply 300 miner's inches for fifteen hours for hydraulicking at a head of 150 feet. The dam is 15 feet high and the reservoir is filled from the supply ditch in from a few hours to three days, according to the rains, which are exceedingly variable. This reservoir, which is built at the elevation of the top of the ancient base-level above the highest gravels, is representative of the best that can be accomplished in this line in the interior

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Yukon-Tanana field. Mr. J. P. Hutchins[a] states that during the summer of 1904 a reservoir was built in the Klondike which has a capacity of 26,000,000 gallons and requires a dam 40 feet in height.

Many small reservoirs (see Pl. XXI, *B*) are used in the North, affording from 50 to 100 inches of water for a run of a few hours. Reservoirs for the providing of sluicing water for winter dumps have been built on Anvil Creek for catching snow water. In some cases even snow fences have been erected behind the dams to increase the size of the snowdrifts.

The Alaskan miner has at hand the vegetable sod or peat, a material which has proved efficient under Alaska conditions for the building of small dams. The construction of dams is discussed on pages 56–57. In building small storage reservoirs for hydraulicking, it is as necessary in Alaska as elsewhere to determine the proper elevation, to select as large a catchment area as possible, and to take into consideration absorption, evaporation, and the character of the ground and underlying bed rock. The angle of slope for a peat dam, as given by J. T. Fanning,[b] is 2.75 horizontal to 1 vertical. Experience has shown that in Alaska, owing to the permanent frost, such dams will stand at a smaller angle, especially if brush is laid alternately with sod. The cost of storage dams in the interior may be reckoned at $1.75 per cubic yard of earthwork, and in Seward Peninsula at $1 per cubic yard.

The expedient of building settling ponds must be resorted to in places where a small amount of sluice water is used over and over for successive operations, as on Anvil Creek, in Seward Peninsula. Two such dams for retaining sediment, one of which is shown in Pl. XXII, *A*, are in use on Anvil Creek. The water is drawn off from these as often as possible. In the second case it is drawn off at intervals of ten hours to the supply flume.

## PIPE LINES.

In hydraulic mining the water is distributed from the pressure box to the monitors and elevators by means of wrought-iron or, more generally, steel-riveted pipe, usually made up in sections 17 to 19 feet in length. Sheet steel is used, from 8 to 16 U. S. standard gauge, bent, each plate, 30 or 36 inches in length, being riveted in double rows lengthwise and single on the ends. The sizes used in Alaska vary from 8 to 36 inches. The pipe is shipped by the manufacturers either made up and riveted, as above, ready to be laid with slip joints, or the material is supplied in short plate sections, bent, punched, and furnished with necessary rivets, baled and nested for transportation, ready to be cold riveted on the ground. Fig. 22 shows a form of ship-

[a] Eng. and Min. Jour., Jan. 5, 1905.
[b] Treatise on Water Supply and Engineering, p. 345.

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*A*. SETTLING POND, ANVIL CREEK, SEWARD PENINSULA.



*B*. PIPE LINE, ATLIN CREEK, BRITISH COLUMBIA.

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ping made-up pipe of different diameters which renders it secure from bending or injury in transport. The iron bolt can afterwards be used in the blacksmith shop.

Pipe made up beforehand is coated by immersing it in a bath of asphaltum preparation. This is highly important, and if the operator rivets his pipe on the ground he should dip the pipe in such a bath before laying. Bowie gives the following formula for a bath:

| | Per cent. |
|---|---|
| Crude asphaltum | 28 |
| Coal tar (free from oily substances) | 72 |

The advantages of using sheet steel, commonly called "hydraulic" pipe, are its cheapness of construction, adaptability for crossing depressions (as in inverted siphons), the facility with which its position can be changed, and, when slip joints are used, the ease with which the line can be laid. Many engineers do not recommend the use of slip joints—that is, the slipping of the end of one length of pipe 3 inches into the end of the next to form the joint. With average topography,

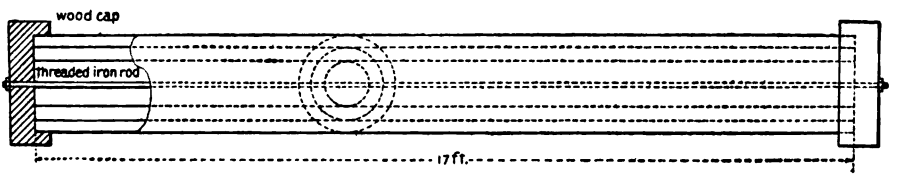



FIG. 22.—Method of nesting made-up hydraulic pipe for shipment.

however, experience has proved that such joints stand great pressure, and the practice is nearly universal among hydraulic miners.

Pipe is used for the three following purposes:

(1) As a water conduit, replacing ditches and flumes. Pipe is not recommended for this purpose except where siphoning is necessary or where conditions are particularly difficult for ditching and fluming.

(2) For leading water from the pressure box to the claim.

(3) For leading the water from the gate of a Y to its various points of discharge, as to giants, elevators, and impulse or "hurdy-gurdy" wheels.

The discharge pipe is generally a nozzle, either manipulated by means of a swivel-jointed tapering pipe called a giant or monitor or fixed within a larger pipe (the contrivance known as an elevator), or acting on the buckets of a wheel.

The thickness of the iron or steel employed is determined by the pressure of the water and the diameter of the pipe. Table 9 gives information concerning a few of the sizes used in Alaska. Prices are those prevailing in San Francisco.



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TABLE 9.—*Double-riveted sheet steel slip-joint hydraulic pipe.*

| Diameter in inches. | Thickness, U. S. gage. | Thickness in fractions of an inch. | Head, in feet, pipe will safely stand. | Pressure in pounds per square inch due to head. | Weight per foot in pounds. | Price per foot, San Francisco, 1904. |
|---|---|---|---|---|---|---|
| 6 | 18 | 1/20 | 480 | 208 | 3.80 | $0.23 |
| 6 | 16 | 1/16 | 600 | 260 | 4.85 | .25 |
| 8 | 16 | 1/16 | 450 | 195 | 6.30 | .32 |
| 8 | 14 | 5/64 | 563 | 244 | 7.75 | .35 |
| 11 | 16 | 1/16 | 325 | 141 | 8.50 | .37½ |
| 11 | 14 | 5/64 | 408 | 177 | 10.50 | .44 |
| 11 | 12 | 7/64 | 572 | 248 | 14.50 | .60 |
| 15 | 18 | 1/20 | 191 | 83 | 8.50 | .46 |
| 15 | 16 | 1/16 | 240 | 104 | 10.75 | .50 |
| 15 | 14 | 5/64 | 300 | 130 | 13.00 | .55 |
| 15 | 12 | 7/64 | 420 | 182 | 19.00 | .85 |
| 18 | 10 | 9/64 | 450 | 195 | 30.00 | 1.50 |
| 22 | 16 | 1/16 | 164 | 71 | 15.75 | .70 |
| 22 | 12 | 7/64 | 286 | 124 | 28.50 | 1.20 |
| 24 | 16 | 1/16 | 150 | 65 | 18.00 | .80 |
| 24 | 14 | 5/64 | 187 | 81 | 22.00 | 1.00 |
| 30 | 16 | 1/16 | 120 | 52 | 21.00 | .90 |
| 30 | 14 | 5/64 | 150 | 65 | 27.00 | 1.10 |

Pipe-reducing sections, Y's, forks, and elbows, and the method of "nesting" pipe for shipment are illustrated by fig. 23 (p. 131). Sections of pipe are put together, as above stated, by slipping, or by flange or lead joints. If it is advisable to reenforce a slip joint, the simple device shown in fig. 24 (p. 132), which can be made quickly in the blacksmith shop, will be found useful. The sleeve, lugs, and key should be made of soft steel.

The disadvantage of diverting water from a straight pipe line may be illustrated by the experience of one of the Alaska operators. It was found that diverting the water from an 18-inch plugged pipe by means of 6-inch Y branch gave an efficiency of 2, while in using the same water through the direct 18-inch pipe choked to 6 inches the efficiency was 3.

In laying pipe from the pressure box to the claim the line should be started at the lower end and the joints slipped in down the slope. Various methods of "setting" the pipe are in use. The device shown in fig. 25 is used by Mr. F. H. Brackett, of Atlin, British Columbia. It consists of a square block of timber 3 by 3 feet by 9 inches, faced with one-sixteenth inch steel plate, to which is bolted a disk-like wooden plug the diameter of the pipe inside. Two men batter the timber with

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the mallet. Another device used in Oregon for assistance in setting and unsetting pipe is shown in fig. 26. The wrench is made with reversible parts, so that the position of the leverage can be changed for the different operations. Either of these devices can be easily made on the ground.

In cold climates it has been found good practice to lay the pipe line in a slight lateral curve down a slope, so that subsequent contraction of the units may be remedied by pushing the pipe into a more nearly straight line.

In laying the pipe line a funnel-shaped section of pipe for the water to run into is usually provided at the pressure box. This is of light gage and is 6 feet long and from 40 to 30 inches at its larger end. From this the pipe is generally of uniform diameter as far as the Y or iron gate, from which the water is distributed to various parts of the operations. The pipe should be laid as nearly straight as conditions will allow, and elbows and bends of small radius should be avoided.

Lead joints are seldom necessary in Alaska operations, but where there are sharp declivities pipe joints must be braced and strengthened by means of lugs and wiring, as illustrated in fig. 27. It is seldom possible to lay pipe on the "hydraulic grade line."[a] This is "an imaginary straight line, extending from a point on the side of the water box or reservoir, denominated the velocity head, to the mouth of the nozzle." When the pipe line departs greatly from the hydraulic grade line, allowances based on formulas given in the various textbooks on hydraulic mining must be made for the difference in pressure.

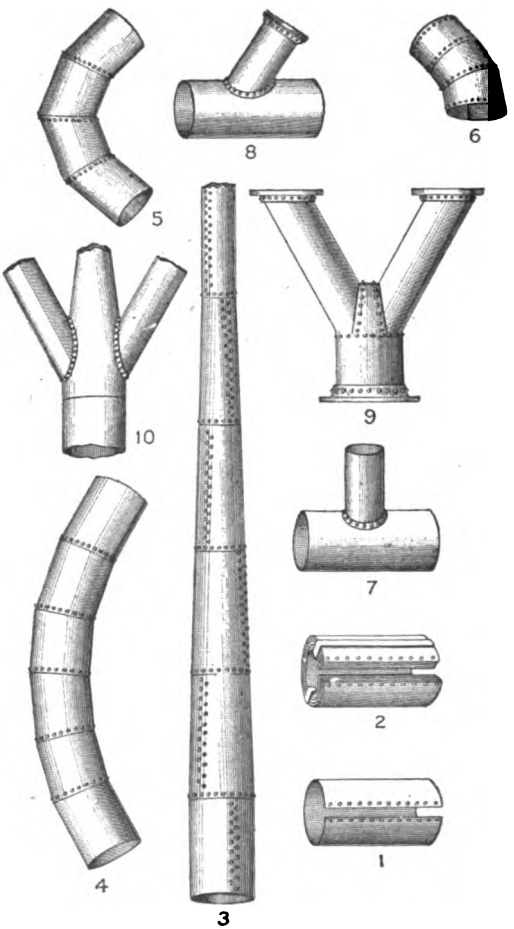



FIG. 23.—Forms of pipe fittings. 1, Pipe cut, formed, and punched, to be rivited on ground; 2, pipe nested for shipment; 3, reducing length; 4, circular bend; 5, angular bend; 6, short angular bend; 7, T discharge; 8, angular T discharge; 9, two-way Y; 10, three-way Y.

[a] Van Wagenen, op. cit., p. 69.

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Where 22- to 30-inch pipes are used it is not advisable to employ less than 14 gage, even under low heads, as lighter pipe will not bear handling. The practice of burying pipe, or at least sodding it over, where the line is to be in place for more than a season, is recommended in Alaska even more than in other countries.

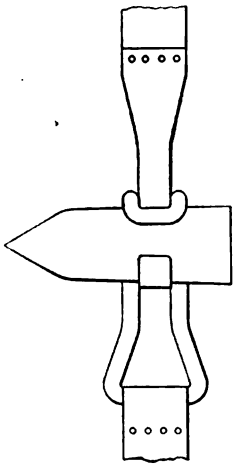


FIG. 24.—Device for reenforcing joints of pipe.

Air valves, which can be simply made of leather, hinged to the inside of 3-inch openings in the pipe, should be not more than 300 feet apart. These allow the air to escape when the pipe is being filled and prevent the collapse of the pipe when suddenly emptied of water. Leakage in joints may frequently be stopped by slowly feeding sawdust or manure in at the upper end. In case of collapse of a pipe line, experience has shown that by turning on the water slowly, after closing the lower end, the collapsed sections may be restored to shape for temporary use. The experiment is risky.

Pl. XXII, *B*, shows the set-up of a hydraulic pipe line on McKee Creek, Atlin. As may be seen, the line is well braced and rock ballasted, and on steep places the joints are held by lugs and wire guys. The line, which is one of three in use on this property, is of 12-gage steel, is 1,200 feet in length, has a 30-inch mouthpiece at the penstock, and is successively reduced to 18, 16, and 12 inches, the last discharging through the giant. At full capacity the discharge was said to be 700 miner's inches at 170-foot head. The discharge was through a No. 4 Vancouver giant, using 6-inch nozzle, the average twenty-four hour duty being 4 cubic yards of gravel. Along the pipe line side ditches were cut for a short distance to take care of leakage. Pl. XXIII, *A*, shows a pipe line led down a hillside on Pine Creek, Atlin.

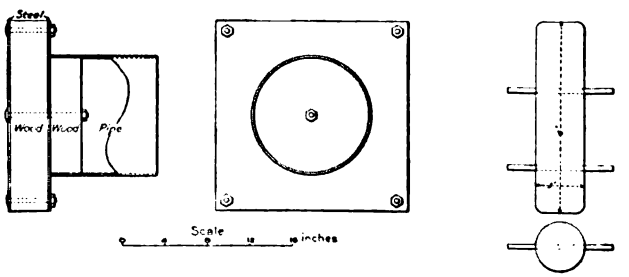


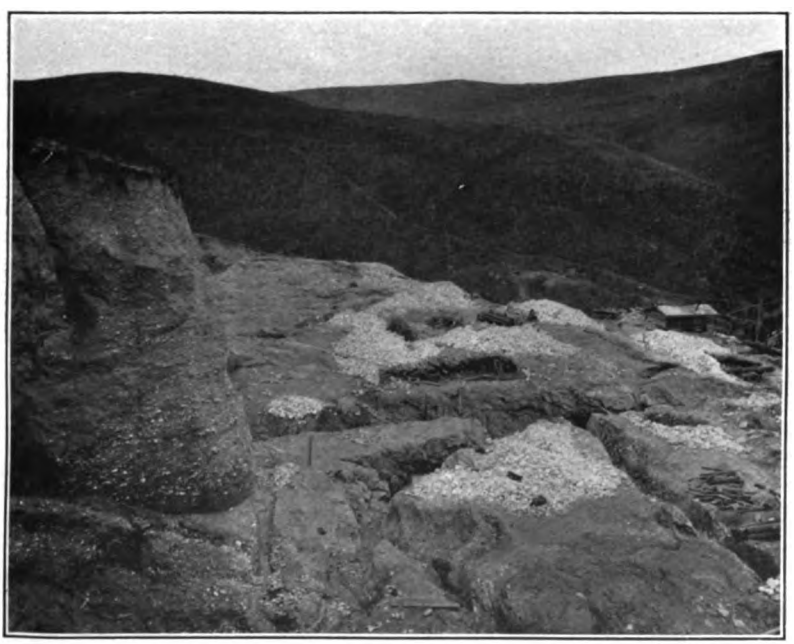

FIG. 25.—Device for setting pipe by battering.

An important fact regarding the flow of water in pipes is the loss of effective pressure at the nozzle due to friction, owing to the use of pipes of too small diameter. The friction of water in pipes increases

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*A.* SET-UP OF HYDRAULIC PIPE LINE, McKEE CREEK, ATLIN, BRITISH COLUMBIA.



*B.* HYDRAULIC PIT, KLONDIKE BENCHES.

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as the square of the velocity and also depends on the condition of the pipes. Even the rivet heads in a pipe line cause friction and consequent loss of head. As Mr. George H. Evans[a] points out, it makes no difference whether the water is flowing up hill or down, or the pressure great or small, the total friction will be materially the same.

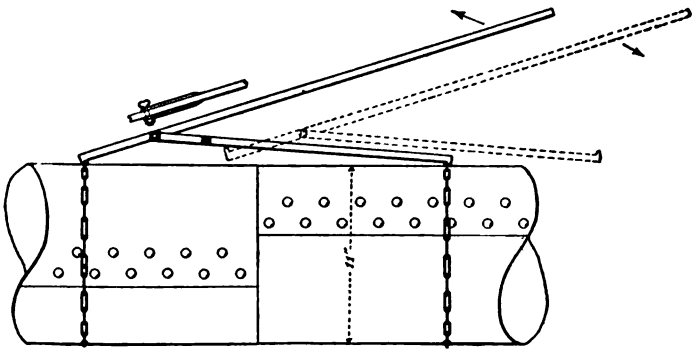


FIG. 26.—Pipe wrench for setting and unsetting hydraulic pipe.

In wooden pipes the friction is nearly double that in iron or steel pipes. Cox's formula for finding the friction head, which must be subtracted from the actual head to give the effective head, is as follows:

$$H = \frac{L}{1200d} \times (4 \times V^2 + 5V - 2)$$

H = friction head in feet.
$d$ = diameter of pipe in inches.
L = length of pipe in feet.
V = velocity of water in feet per second.

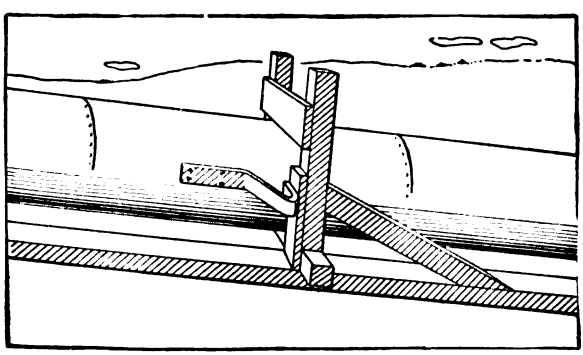


FIG 27.—Method of bracing hydraulic pipe on steep slope.

The loss in head of a pipe line 12 inches in diameter, discharging 400 miner's inches, and 5,000 feet in length, is computed by Mr. Evans to be 246.44 feet. Or, if the actual head is 500 feet, the effective head is reduced to 253.56 feet, or an original pressure of 217 pounds per square inch to 110 pounds. To find the velocity in feet per minute in

[a] Practical Notes on Hydraulic Mining, San Francisco, 1898, p. 25.

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a pipe, multiply the number of cubic feet of water discharged per minute by 144, and divide the product by the area of the pipe in square inches. The velocity in feet per second can then be found.

Experiments by Mr. Hamilton Smith[a] appear to demonstrate that with new and carefully coated pipes, with velocity as high as 11 feet per second, the loss of head is not significant. Nevertheless, the numerous conditions which enter into the laying of pipe lines on placer mines render the rule that the velocity should not exceed 3 feet per second in the pipe a very safe one to follow. It is a common fallacy among men inexperienced in hydraulicking that an increase in head will increase the amount of gravel which can be moved to the sluice. It must be remembered that the force of the water imparted by head is entirely expended in piping against the face, while the sluice is the governing factor in the moving of gravel after it leaves the face. The aid given by the water in moving gravel to the sluice, and in it is dependent on the grade over which it runs. In small hydraulic operations water is conducted to the pit from the head ditch or penstock by means of canvas hose, known as flume hose, which is from 6 to 14 inches in diameter and weighs from 8 to 15 ounces per foot. This is used mainly on account of its cheapness and, as a less important consideration, because of the ease with which it may be moved about. It is used also for conveying water with very low head, for sluicing purposes.

Flume hose is at best a makeshift and its use is not recommended, except in operations of primitive character in very remote districts. It should never be used to handle more than 100 inches of water or for a head greater than 50 feet.

## GIANTS AND NOZZLES.

### SIZES AND PRICES.

The practice in using hydraulic discharge pipes, known as monitors, giants, and nozzles, does not differ in Alaska from that pursued elsewhere.

Table 10 gives the principal facts necessary for the miner to know about hydraulic giants of the size most applicable for Alaskan work.

[a] Smith, Hamilton, Hydraulics, 1886, p. 314.

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TABLE 10.—*Water required, effective work, sizes, volumes, and heads of water, weights and prices of double-jointed hydraulic giants.*

[Prices include two nozzles to each machine and are subject to discount.]

| No. of giants. | Diameter of pipe inlets. | Diameter of butts with nozzle detached. | Size of nozzles. | Effective head or pressure. | Volumes of water necessary for effective work. | | Weights of heaviest part. | Shipping weights. | List price, 1904. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Double-jointed, ball-bearing. | Double-jointed, plain. |
| | *In.* | *In.* | *In.* | *Feet.* | *Miner's inches.* | *Miner's inches.* | *Lbs.* | *Lbs.* | | |
| | | | | | 1-inch nozzle. | 1½-inch nozzle. | | | | |
| 0 | 5 | 2½ | 1, 1½ | 100 | 20 | 45 | 100 | 330 | $100 | $85 |
| | | | | 150 | 25 | 55 | | | | |
| | | | | 200 | 30 | 65 | | | | |
| | | | | | 2-inch nozzle. | 3-inch nozzle. | | | | |
| 1 | 7 | 4 | 2, 3 | 100 | 80 | 185 | 120 | 390 | 140 | 125 |
| | | | | 200 | 115 | 260 | | | | |
| | | | | 300 | 140 | 320 | | | | |
| | | | | 400 | 160 | 365 | | | | |
| | | | | | 3-inch nozzle. | 4-inch nozzle. | | | | |
| 2 | 9 | 5 | 3, 4 | 100 | 185 | 325 | 150 | 520 | 195 | 175 |
| | | | | 200 | 260 | 460 | | | | |
| | | | | 300 | 320 | 565 | | | | |
| | | | | 400 | 365 | 650 | | | | |
| | | | | | 3-inch nozzle. | 4-inch nozzle. | | | | |
| 3 | 11 | 6 | 3, 4 | 100 | 185 | 325 | 210 | 890 | 250 | 225 |
| | | | | 200 | 260 | 460 | | | | |
| | | | | 300 | 320 | 565 | | | | |
| | | | | 400 | 365 | 650 | | | | |
| | | | | | 4-inch nozzle. | 6-inch nozzle. | | | | |
| 4 | 11 | 7 | 4, 6 | 100 | 325 | 730 | 225 | 1,075 | 275 | 250 |
| | | | | 200 | 460 | 1,000 | | | | |
| | | | | 300 | 565 | 1,270 | | | | |
| | | | | 400 | 650 | 1,460 | | | | |

About 70 giants of several different makes were in operation in the territory visited during the summer, of which 58 per cent were of size No. 2, using commonly a 3-inch nozzle. In the Juneau and Atlin districts size No. 4, using 4- and 6-inch nozzle, is used as a rule, while in the interior and Seward Peninsula the sizes 0, 1, and 2, using from 2- to 4-inch nozzle, are preferable. The double-jointed, ball-bearing giant is the favorite type. Deflectors are not commonly used with

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sizes below No. 2, while in working on the Klondike benches the practice is in favor of butt ends even with larger giants.

The giants used in Alaska are almost exclusively of California manufacture, although in the Atlin and Klondike districts some of Canadian make are used. The importance of using water as free as possible from solid matter in suspension should be considered and great care should be taken to trap all foreign material at the pressure box. The rifling in the barrel of the monitor and the boring of the nozzle are also of the first importance, and operators will find it expensive to use other than standard and well-tried makes of giants. A method of bracing giant is shown in fig. 28. In soft schist bed rock, however, it is frequently necessary to brace with deadman and cable.

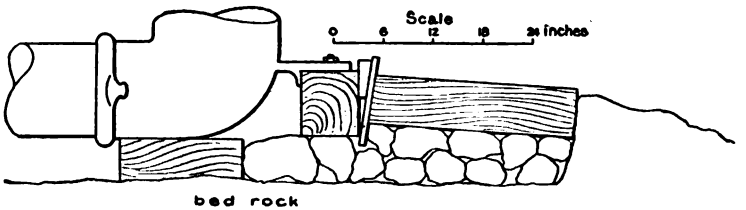



FIG. 28.—Method of bracing giant.

## METHODS OF PIPING TO SLUICE.

It has been found that some operators in the north are in favor of setting the giant on the top of the bank and piping downstream. This is the practice on McKee Creek, Atlin district, and in the Nome and Council districts. Although the duty attained by the miner's inch does not prove this to be advantageous, it should be remembered that the height of bank to be operated on is generally small—from 15 to 50 feet. There is little caving to be done with the pipe, and except in the case of the rounded gravels of the Klondike "White Channel," it is thought that the water under pressure assists in moving the material to the sluice. Experience does not indicate that the attempt to drive the gravel with the nozzle is very effective.

The various precautions concerning keeping the gravel bank square, the prevention of dangerous caves, and the necessity of continuous work during the short season are well known to the hydraulic miner in any country. In working the shallow gravel banks of Alaska it should be borne in mind that the giants must be frequently moved and the tail sluice extended. These operations consume time, and the most expeditious system possible for performing them should be adopted at the commencement of the short season.

Fig. 29 shows the method of rigging up a hydraulic mine on one of the narrow benches of White Channel gravel bordering Bonanza Creek in the Klondike, and Pl. XXIII, *B*, shows a portion of the ground which has been worked as indicated in the sketch.

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*A.* BED-ROCK SLUICE, KLONDIKE BENCHES.



*B.* BLOCKS OF FROZEN GRAVEL IN HYDRAULIC PIT, KLONDIKE.

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In piping against a 40-foot bank of frozen gravel, as here illustrated, it has been found good practice to use the giant against a certain part of the bank from two to six hours a day, and allowing the gravel to thaw the remainder of the twenty-four hours. Piping continuously against a frozen bank is a waste of water and power. (See Pl. XXIV, *B*.) The use of powder is of no avail. Even if the gravel is broken off and moved to the sluice in frozen chunks it can not be washed nor can the gold be extracted from it. A combination of water under pressure and of the action of the sun, rightly adjusted, is most effective in thawing frozen gravel. Mr. J. P. Hutchins says that for 200 to 250 miner's inches of water a face covering 50,000 square feet should be allowed on the shady side of hills, while a much less surface will suffice on a sunny slope.

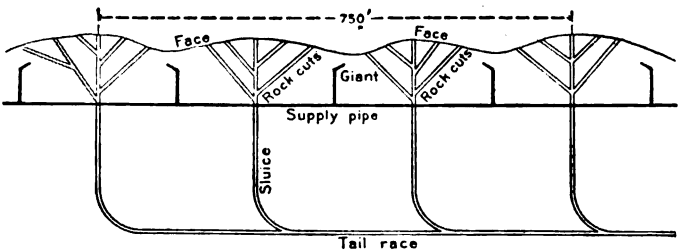



FIG. 29.—Method of hydraulicking frozen gravel, Klondike benches.

It will be noticed that in the Klondike operations here figured deep trenches or "ground sluices" are cut in the bed rock leading from the face to the head of the tail sluice. The cutting and constant extension of such trenches is a necessity in almost any hydraulic operation, to a greater or less extent, and forms a considerable item of expense. At the time here figured four men in twenty-four hours were employed all the time in blasting out the bed-rock cuts, the expense amounting to not less than $50 a day. In some cases the bench miners have sunk a shaft at a central part of the ground and run a long tunnel on the grade of the sluice, to which all the gravel is moved. Although such tunnels carrying the tail sluice will be from 200 to 500 feet in length, and will cost from $3,000 to $10,000, they will generally be found less expensive than the constant cutting of trenches to connect with the main sluice carried as shown in the plant.

### BANK-HEAD WATER.

In no case seen in the North has the amount of bank-head water been excessive. This is a useful accessory to the mining operations, and where it is available should be used. The width of tail sluices should be great enough to allow for excess water, as at times of local rains such water can frequently be obtained and a larger amount of gravel thereby assisted in reaching the sluice.

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Pl. XV, *B* (p. 92), shows hydraulic operations in Silver Bow basin, Alaska, and illustrates the use of the bank-head water.

### DUTY OF A MINER'S INCH.

This term is applied to the quantity of material moved by 1 inch of water in twenty-four hours. It depends on quantity of water, character of material washed, height of bank, size and grade of sluice, and kind of riffle. In many mines the gravel may be easily broken down and carried to the sluice, but may be very hard to move through the sluice on account of a light grade, disproportionate width of box, or the use of obstructive riffles. Thus, according to Bowie, in the North Bloomfield mine the duty varied from 3.86 to 4.8 cubic yards, with 100 to 265 feet of bank, sluice 6 feet wide by 32 inches deep, grade 6½ inches in 12 feet. At La Grange mines, on the other hand, the duty was from 1.08 to 1.82 cubic yards, height of bank 50 to 80 feet, sluice 4 feet wide, 30 inches deep, and grade 3 inches in 12 feet. In both cases the riffle pavement was principally blocks.

Table 11 (p. 139) is instructive as showing the variation in duty of the miner's inch under the different governing conditions in the North. The duty of the miner's inch in the Klondike is large, estimated at 8 cubic yards in twenty-four hours in the operation described on page 137, with water under 130-foot head and a grade of 12 inches to 12 feet in the sluice boxes, a variable amount of bank-head water from 25 to 100 miner's inches being used. The high duty is accounted for by the fact that the material washed is well rounded, by the absence of large stones, heavy grades to sluices, and the fact that block riffles are generally employed.

The low duties at Nome are accounted for principally by the fact that one-half to two-thirds of the water is generally diverted for use in the hydraulic tailings lifts, and partly by the fact that the gravel is flat and rough. Iron riffles are generally used, but this factor plays little part on account of the short sluices in use.

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TABLE 11.—*Duty of the miner's inch in northern placer mining.*

[The estimates are based on statements made by the operators.]

| Locality. | Height of bank. | Grade. | Miner's inches of water. | Cubic yards duty. | Sluice dimensions. | | Riffles. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Width. | Depth. | | |
| Juneau: | *Feet.* | | | | *Inches.* | *Inches.* | | |
| Windfall Creek | 16 | ..... | 1,000 | 2 | ..... | ..... | ..... | |
| Gold Creek | 200 | 4¼ inches : 12 feet | 4,000 | 2 | 72 | 60 | Blocks | Heavy stones |
| Silver Bow basin | 80 | 4 inches : 12 feet | 2,500 | 2 | 50 | 55 | .....do | Do. |
| Atlin: | | | | | | | | |
| McKee Creek | 40 | 8 inches : 12 feet | 700 | 1½ | 32 | 32 | Angle iron and blocks | Do. |
| Do | 85 | 8 inches : 12 feet | 1,200 | 3 | 32 | 40 | .....do | Do. |
| Birch Creek | 25 | 5½ inches : 12 feet | 1,200 | ¼ | 30 | 30 | Blocks | Do. |
| Spruce Creek | 29 | 5 inches : 12 feet | 1,200 | 1 | 40 | 36 | .....do | Do. |
| Do | 20 | 5½ inches : 12 feet | 900 | ¼ | 48 | 32 | .....do | Do. |
| Pine Creek | 20 | 3 inches : 12 feet | 700 | ⅜ | 36 | 36 | Long rails | Do. |
| Do | 60 | 5 inches : 12 feet | 3,500 | ¼ | 60 | 40 | Block | Do. |
| Dawson: | | | | | | | | |
| Bonanza Creek | 20 | 12 inches : 12 feet | 250 | 5 | 24 | 20 | Blocks | "White Channel" small round gravel, frozen. |
| Do | 25 | 12 inches : 12 feet | 125 | (?)4 | 20 | 16 | Sawed pole, iron-shod | Hillside, small gravel, frozen. |
| Do | 25 | 11 inches : 12 feet | 150 | 10 | 24 | 24 | Blocks | "White Channel" small round gravel, part tailings. |
| Do | 35 | 12 inches : 12 feet | 200 | 6½ | 24 | 24 | .....do | "White Channel" small gravel, frozen. |
| Do | 75 | 12 inches : 12 feet | 266 | 8 | 24 | 30 | .....do | Do. |
| Eldorado Creek | 60 | 11 inches : 12 feet | 160 | 7 | (?) 24 | 24 | Iron, Hungarian, and blocks | Do. |
| Last Chance | 46 | 12 inches : 12 feet | 230 | 7 | 24 | 18 | Pole, iron-shod, and blocks. | Do. |
| Do | 25 | 14 inches : 12 feet | 120 | 5 | 20 | 20 | Pole, iron-shod | Do. |
| Hunker Creek | 15 | 13 inches : 12 feet | 150 | 2 | 14 | 14 | Pole and blocks | "White Channel," very little frozen. |
| Do | 8 | 12 inches : 12 feet | 125 | 2⅜ | 17 | 14 | Pole, iron-shod | "White Channel" small gravel, frozen. |
| Nome: | | | | | | | | |
| Anvil Creek | 30 | 4½ inches : 12 feet | 500 | 1⅛ | 33 | 18 | Angle iron | Heavy partly frozen gravel, much flat schist. |
| Do | 20 | 4½ inches : 12 feet | 400 | 10 | ..... | ..... | .....do | Frozen earth or "muck" stripping. |
| Do | 12 | 9 inches : 12 feet | 100 | ..... | 16 | 14 | .....do | |

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TABLE 11.—*Duty of the miner's inch in northern placer mining*—Continued.

| Locality. | Height of bank. | Grade. | Miner's inches of water. | Cubic yards duty. | Sluice dimensions. | | Riffles. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Width. | Depth. | | |
| Nome—Continued. | *Feet.* | | | | *Inches.* | *Inches.* | | |
| Anvil Creek | 4½ | 3 inches : 12 feet | 100 | 3 | (a) | (a) | | Frozen muck, 75 per cent ice, ditch head. |
| Glacier Creek | 20 | 6 inches : 12 feet | 760 | 1.32 | 36 | 24 | Angle-iron grates | Two-thirds water used for lifting 36 feet flat semi-frozen gravel. |
| Dexter Creek | 40 | 6½ inches : 12 feet | 100 | (?)2 | 16 | 16 | do | Heavy gravel, limestone bed rock. |
| Newton Creek | 8 | 7 inches : 12 feet | 150 | 3½ | 24 | 24 | Pole and angle iron | Small coastal plain gravel. |
| Basin Creek | 20 | 8 inches : 12 feet | 250 | .6 | 18 | 18 | Pole, iron-shod | Elevator using three-fifths water, 29 feet lift, heavy gravel. |
| Council: | | | | | | | | |
| Ophir Creek | 12 | 10 inches : 12 feet | 600 | 1½ | 24 | 16 | Rails and angle iron | Elevator using three-fifths water, 29 feet lift, heavy gravel. |
| Do | 8 | 10 inches : 12 feet | 750 | 1 | 24 | 16 | do | Elevator using two-thirds water, 28 feet lift, slabs and clay. |
| Crooked Creek b | 4 | 4½ inches : 12 feet | 55 | 3.45 | (a) | (a) | | Frozen muck, ground sluice, ditch head. |
| Solomon: | | | | | | | | |
| Solomon River | 5 | 10 inches : 12 feet | 600 | .8 | 37 | 24 | Angle-iron grates | Elevator using one-half water lift, 12 feet subangular gravel. |

a Ground sluice.

b Ground sluicing of frozen "muck" material consisting of 50 to 75 per cent ice.

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The duty given above is based entirely on statements made by the operators, and owing to the short amount of running time which has furnished the data, no particular case can be considered of high authority. It will be seen, however, that the different operations in each separate province present a certain amount of agreement.

In stripping operations where the "frozen muck" is removed by water, ground sluicing appears to be nearly as efficient as the use of water through the nozzle, both in the interior and Seward Peninsula. This peculiar material, from 50 to 75 per cent ice, is easily thawed when exposed to the atmosphere and to flowing water. It appears rather to be melted than cut away, therefore the impact of a hydraulic stream adds little to the efficiency of a given quantity of water.

It is stated by the Klondike operators that were the "White Channel" gravels unfrozen the duty of the inch would be twice as large. This is not impossible, as the bench gravel presents most favorable characteristics for easy handling. In its frozen state, however, the bank has the consistency of fresh granite.

In Seward Peninsula the instances tabulated are mostly those where hydraulic lifts are employed. The duty has been given in terms of the total amount of water used, including bank head, monitor, and elevator water. In the cases where elevators are used the grade and dimensions refer to the bed-rock sluice leading to the throat, and do not refer to the tail sluice.

## HANDLING OF BOWLDERS.

The handling of large bowlders in northern hydraulic operations does not present serious problems. Where hydraulicking is possible it is generally found that all the material is small enough to go through the sluice. In the districts visited during the season's work the Atlin district, of northern British Columbia, was characterized by gravels containing large bowlders, which had to be derricked out or sledged in the pit. The practice of "bulldozing" or "plastering" bowlders to break them, by placing sticks of powder on top, covered with a mud cap, is not to be recommended on account of the expense of powder. Sledging into pieces small enough to be sent to the sluice will generally be found the cheapest method, especially as bowlders consisting of hard and tough rocks are not frequently encountered.

Mr. J. D. Hauer, in a recent article,[a] states that in general contract work under given conditions the cost of sledging sandstone bowlders varied from 1 to 9 cents per cubic yard; "mud capping" or "bulldozing" costs from 18 cents to as much as 51 cents; "blocking," or breaking by drilling and blasting, costs from 11 to 18 cents; while the method of placing the powder charge under the bowlders costs from

[a] Engineering News, quoted in Mining and Scientific Press, Feb. 9, 1905.

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15 to 17½ cents per cubic yard. He recommends the method last mentioned as against bulldozing, or placing charge on top, as powder is saved and there is the additional advantage that much of the rock is thrown out of the cut.

The practice of installing large and expensive derricks as an adjunct to hydraulic mining is not generally recommended for Alaskan work.

## SLUICES AND GOLD-SAVING APPLIANCES IN HYDRAULIC OPERATIONS.

In the South Coast region the plant of the American Gold Mining Company in Silver Bow basin is characteristic. This sluice, while not in use during the season of 1904, has been operated since 1901, and is typical of the most favorable conditions under which hydraulic tail sluices can be constructed in southeast Alaska.

A 9- by 10-foot tunnel, 3,300 feet in length, was driven through a spur of the mountain from the bank of Gold Creek to tap the gravel pit at the proper depth for reaching the lowest sag in the bed rock. The grade of the tunnel, like that of its contained sluice, is 4 inches to 12 feet. It was driven with air at the rate of 8 feet a day in slate, at a cost of $20 per foot. No timbering is used, with the exception of a few sets near the ends.

The sluice running through the tunnel is 4 feet wide and 4 feet 10 inches deep, inside measure, of 2-inch native lumber, lined with 1-inch "sand" or lining boards, all lumber planed and sized. The sills are laid on bed rock, and are 6 inches square and 5 feet long, the posts being also of the same size. Posts and sills are braced by 1 by 8 inch pieces. The sluice is 3,700 feet long from the tunnel entrance and extends for 900 feet up the bed of the pit through the worked-out ground. Bowlders as large as 10 inches in diameter are handled in this sluice without difficulty. The amount of water used varies according to the season, but averages 2,500 inches. Riffles are 12- by 12- by 12-inch spruce blocks set on end, separated by 1¾- by 2-inch strips, set on edge and nailed with headless nails. The duty of a miner's inch of water is 2 cubic yards per twenty-four hours. The amount of lumber necessary for constructing one box of a sluice, such as the above, approximately 1,100 feet, is probably excessive for the needs of the case. Local conditions in the North frequently result in increased expenditure for the sake of hastening work. About 25 pounds of nails were consumed to each box, and $10 worth of labor. The cost will not fall greatly below $30 per box of 12 feet, exclusive of cost of tunneling and shooting out the bed rock to grade in carrying up the boxes through the pit. The annual cost of maintenance, including renewal of riffle blocks, which last two years, and renewal of lining boards, is approximately $1,000 a year.

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In the saving of the gold, which is fine and rough, 23 flasks of quicksilver are distributed in the boxes. One flask of quicksilver is consumed per month.

Six undercurrents are placed near the end of the sluice, within a length of from 300 to 500 feet of the end. They are transversely arranged, 24 by 14 feet in dimensions, and on a grade of 10 inches to 12 feet. They are furnished with Hungarian riffles—wooden strips with flat strap iron nailed to the top.

The first 600 feet of the sluice are cleaned up monthly, and in this length 75 per cent of the gold is said to be saved. The remainder of the sluice is cleaned up once a year. The experience with the undercurrents was not satisfactory, as very little gold was caught in them.

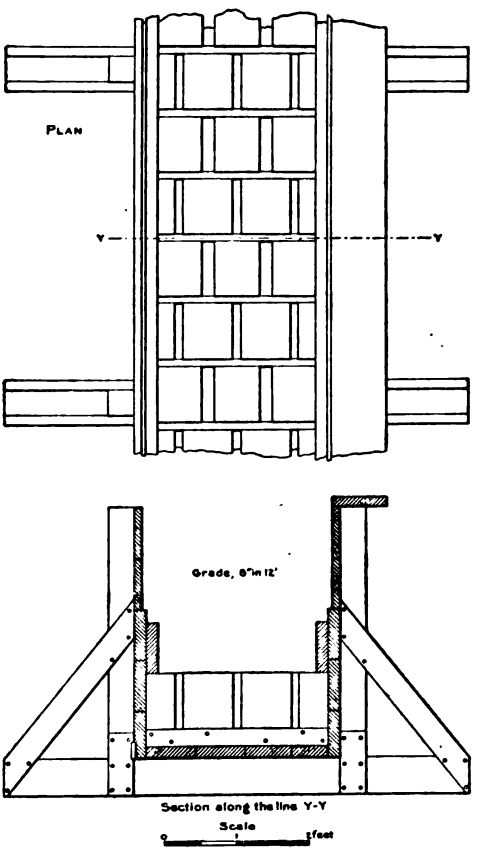



FIG. 30.—Sluice box used on McKee Creek, Atlin, British Columbia.

It should be especially noted that in the South Coast province the placer gold is of recent origin, is not removed more than a mile from its original source, is low in fineness (in the present case $16.50), and is bright and rough. However finely divided, such gold is easy to save, and the advantage of undercurrents may be questioned. In the interior of Alaska the case is different, as will be seen.

In the Atlin district of British Columbia the grades attainable in the tail sluices are generally low, from 3 to 5 inches to the box length of 12 feet. McKee Creek forms an exception to this rule, the grade being 8 inches in the sluices of both the plants now operating there. The practice of the Amalgamated McKee Creek Mining Company on this creek is as follows:

The sluices, of which there are two, are 600 and 700 feet long. The grade is 8 inches to 12 feet, and the inside dimensions of the sluice, exclusive of lining boards, are 29 inches wide by 38½ inches deep, as illustrated in fig. 30.

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The amount of lumber in a sluice box like that figured is as follows:

8 posts, 4 by 4 inches by 3½ feet.
4 sills, 4 by 6 inches by 6 feet.
16 braces, 1½ by 4 inches by 1 foot.
1 top rail, 1½ by 8 inches by 12 feet.
16 post straps, 1¼ by 2 by 4 inches.
3 bottom boards, 1½ by 8 inches by 12 feet.
1 bottom board, 1½ by 4 inches by 12 feet.
4 side boards, 1 by 8 inches by 12 feet.
6 side boards, 1½ by 8 inches by 12 feet.
2 lining boards, 1½ by 8 inches by 12 feet.
48 riffle blocks, 8 by 8 by 12 inches.
16 riffle strips, 1 by 3 by 28 inches.

Each box, with riffle blocks, contains approximately 540 feet of lumber.

The use of 8-inch lumber is a necessity if native timber is used, 12-inch lumber being very scarce and the expense of employing it prohibitive. The cost of each box, including riffles, averages $25, sluice lumber being $45 per thousand and the riffle blocks costing $6 per box length. The setting of the riffle blocks with alternate spacing, as represented, is said to be advantageous, causing a cross circulation and consequent stirring action. The riffles are nailed in sets of three to a riffle strip outside the flume, and are piled up ready to be put in position as occasion demands. Pole riffles, 12 feet in length, made of 3- by 3-inch strips, set with a right-angle uppermost and shod with angle iron, are used in a portion of the boxes. A space is left between the lowest angle and the bottom of the box, the long strips being set with a gain into cross strips, 6 feet apart. The blocks are being gradually replaced by this type of pole riffle. The gold is coarse, and it is said that undercurrents would be of no advantage. In the first box 85 per cent of the gold is caught. In the first five boxes all the gold is caught which pays to clean up. In one clean-up $25,000 was caught in the first box, as against $1,900 in the remainder of the 700-foot sluice. The clean-up of the upper two boxes takes place once in two weeks. In this sluice the miner's inch is said to have a duty of 4 yards. A new box is put on the end of the tail sluice every two days. When the end of the sluice is spread into Y's, a hinged gate, with steel plates on both sides, is used for diverting the water and tailings into one or the other branches.

Experience on McKee Creek appears to show that the gold is saved in a comparatively short distance. Yet gravel miners in California maintain, and with apparent reason, that the longer the sluice the more gold will be saved. For example, at the Hidden Treasure drift mine, in Eldorado County, Cal., it was stated to the writer that the 2,500 feet of sluice boxes, 19 by 21 inches in the clear, with iron car wheel and rack riffles, and an undercurrent attached, were insufficient

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to save the gold. The sluice has a grade of 14 inches to 12 feet, and 90 pounds of quicksilver were used in charging the sluice.

The percentage of gold in the upper 120 feet of the sluice was as follows:

| | Per cent. |
|---|---|
| In upper 1 foot | 75.0 |
| In upper 10 feet | 8.4 |
| In next 50 feet | 9.6 |
| In next 60 feet | 2.0 |

This portion of the sluice was cleaned up monthly, and was furnished with old car wheels, regarded as the best riffle, and with iron Hungarian riffles.

The upper 1,000 feet of the sluice was cleaned up once in three months, and the whole sluice and undercurrents annually. Five per cent of the total product was obtained from the lower 2,380 feet paved with quartz stones, and it is estimated that an amount equal to 2 per cent of the total product escaped into the canyon below. It was stated that one-half mile of this canyon was leased to the Chinese for $5,000 per annum, who cleaned up at a profit the gold which had escaped. The undercurrent was not regarded as of great value, except for the saving of excessively fine gold and free quicksilver and gold with quartz attached.

Mr. W. M. Johnson informed the writer that in Nevada County, Cal., in the case of a sluice 1½ miles in length, the first five out of a total of seven undercurrents proved an economic success, the last two hardly paying to clean up. It was found best to clean the five undercurrents at intervals of two weeks.

The experience on Pine Creek, Atlin, in the matter of saving gold is not so satisfactory as on McKee Creek, according to operators' statements. Pl. XXIII, *A* (p. 132) shows one of the 120-foot sluices of the Pine Creek Power Company. It is 5 feet by 40 inches, has a grade of 5 inches in 12 feet, and is paved with block riffles. The undercurrent, 14 by 24 feet, on a 10-inch grade, was one of the few installations of the kind seen in the northwest. It was understood to be but the beginning of experiments aiming to save the fine gold that escaped with an excessive amount of black sand. The amount of gold recovered is 43 cents per cubic yard, as stated, and the opinion was expressed that a large percentage of fine gold escapes. The undercurrent itself had not been installed a sufficiently long time to determine its efficiency.

The Atlin gold is derived from older gravels through which the present streams cut. The gold is for the most part coarse, but is well rounded. That a certain percentage of it is fine, specimens collected show. It is very probable that an undue proportion of such bench gold will escape from a sluice of the short dimensions figured.



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Drop-offs are not used in any of the sluices seen in Alaska or the North. Grade is lacking, it is true, yet in the case above mentioned there was a space of 25 feet vertically between the end of the sluice and the creek bed which served as the floor of the dump. One or two drops of 6 inches in the short sluice would seem entirely practicable, and would certainly be advisable. Cemented gravel does not occur generally at Atlin, but layers of clay are found in the pay streak. Such clay can not be properly disintegrated in a short sluice, but will roll in balls through the entire string of boxes, carrying with it not only the gold inclosed in its mass, but picking up gold already lying at rest.

A useful device to tighten the bottom boards of sluice boxes before nailing is shown in fig. 31. It is claimed that no tongue and groove are necessary with this appliance.

In the Atlin district the mining operations are hindered by heavy floods in the early part of June. At the property of the Société Minière on Bowlder Creek, it is the practice to cover the sluice with

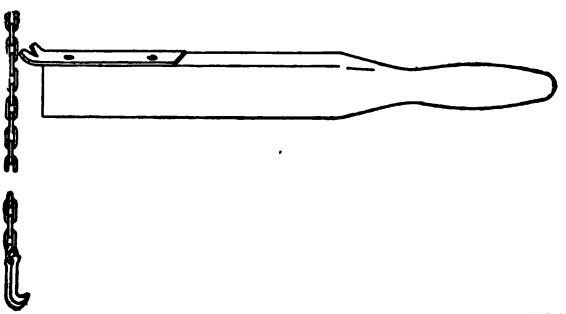


FIG. 31.—Side-board tightener used in making sluice boxes, Atlin, British Columbia.

a series of small protective dams, so that the débris brought down by the annual flood may not injure the boxes. This débris is afterwards piped off, at the cessation of the high water, and the dams are then removed.

The following details of this plant were kindly furnished by M. Henri Maluin, of the Société Minière de la Colombie Britannique, and will be of interest:

The property on Bowlder Creek operated by the Société Minière de la Colombie Britannique is situated in the Atlin mining division of the Cassiar district, British Columbia, 12 miles from the town of Atlin, on Atlin Lake. Operations were started in June, 1901, and the property has been worked continuously during the open season up to the present time. The product of gold has been 3,440 ounces, worth $16.63 per ounce. The gold is rather coarse, and nuggets up to 10 ounces in weight are found. Work is carried on both in the present bed of Bowlder Creek and on benches lying at approximately the same level as the creek bed. The gold-bearing channel is about 150 feet wide, the grade of the creek bed varying from 6 per cent to as high as 10 in the upper end. Where work is now carried on it is 6.1 per cent. The depth of ground averages from 25 to 50 feet, of which the lower 6 feet is consid-

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ered the pay. The bed rock is a soft slate of greenstone variety, although granite occurs at the head of the creek. The gravel to be moved is rather heavy in character, stones from 18 to 30 inches in diameter composing 50 per cent of the mass, though the usual diameter of the stones approximates 6 inches.

In the season of 1904, a season being reckoned at 100 days, with 400 miner's inches of water available, 40,000 cubic yards of gravel were moved, at a cost not far from 50 cents per cubic yard. It is expected that mining will be done in the future for 40 cents per cubic yard, including all expenses. Mr. Maluin states that 35 cents would be a low estimate for the Atlin district, in general, for hydraulic work under the conditions obtaining on Bowlder Creek. Dirt is occasionally moved for 10 cents a cubic yard, and again patches of hard gravel are encountered which cost over a dollar.

An average of 25 men are employed during the summer season at wages of $3 per day of ten hours, and board. The season is open from June 1 to September 15. Spruce and pine are obtainable on the property, though it is difficult to obtain boards wider than 8 inches. Sawed flume lumber costs $40 per thousand.

The water for hydraulicking purposes is brought to the claim from higher up in Bowlder Creek by a flume 3,000 feet in length, size 24 by 24 inches, having a grade of 1 inch in 12 feet. It has an estimated capacity of about 700 miner's inches, but actually 400 inches is generally available at 150-foot head. The pipe line is 16-inch steel to the Y, then 14-inch to the two giants. Vancouver pipe is used, but the giants are California make. The average height of bank is 50 feet, and the giants have no difficulty in cleaning bed rock.

The sluice is 1,400 feet in length and cost $6,000. It is 24 inches wide on a grade of 4 per cent, corresponding very nearly to 6 inches to the 12 feet. Bottom boards are 1½ inches thick, sides 1¼ inches thick, while sills and posts are 4 by 6 inches. It is possible to keep a drop below the end box of 35 feet for dump. In piping, the head box is kept within 30 feet of the bank, and four men for one-half day are needed to place a new box at the head. Block riffles are used at the head of the sluice followed by rails. Very little quicksilver is necessary, and it is found that no gold is recovered beyond 250 feet of boxes. Undercurrents are not used. Bowlders are removed from the pit by flat hand cars running on a steel track. If too large for this, which is seldom the case, they are plastered and shot with 75 per cent dynamite. The company is now in good shape to operate for a period of years, and estimates that the cost will not exceed 40 per cent of the product.

The company leases a portion of its ground where the situation is not advantageous for hydraulicking, and this is drifted. Although the drifting operations are carried on under great difficulties and require close timbering, the work is said to have been profitable.

In the hydraulic mining of the "White Channel" bench gravels of the Klondike, the small amount of water available, generally from 100 to 200 miner's inches, necessitates steep grades to the sluices. The gold is recovered with comparative ease because the bench gravels, after being thawed, are easily disintegrated and washed, and clay is absent from the pay streaks. The sluice shown on Pl. XXIV, *A*, is carried in a cut in the outer rim rock, on a grade of 12 inches to the box length of 12 feet. Twelve to fourteen boxes are ordinarily used. The details of the sluice are as follows: 24 inches wide by 20 inches deep, bottom of 2-inch and sides and lining of 1½-inch lumber; posts and sills 2 inches square; sills set in bed rock; riffles of spruce blocks 5 inches high and 9 inches square. These cost 25 cents apiece and last

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one season. Through this sluice 1,000 cubic yards are washed in twenty-four hours with 250 miner's inches of water. It is stated that 90 per cent of the gold is saved in the upper 6 boxes, only 1 per cent of the total gold being lost. The gold is mostly coarse and rough, but very fine gold is found.

In the case of another operation working the Bonanza Creek benches it was stated that gold was found the entire length of a 2,000-foot bed-rock sluice, followed by 500 feet of 2-foot wooden sluice, on grade of 11 inches to the box length. Block riffles were used in the wooden sluice. A small nugget was picked up 2,000 feet from the head of the sluice. Another operator, using 360 feet of 20-inch sluice boxes, on 12-inch grade, with iron-shod pole riffles, said that 2 per cent of his gold was escaping, and he was of the opinion that the installation of an undercurrent would pay.

In a hydraulic operation using 500 feet of boxes, 2 feet wide, 12-inch grade, with block riffles, and working a portion of the "White Channel" gravels where the gold is very fine, bright, and smooth, it was said that 80 per cent was caught in the top box, 85 per cent inside the first 15 boxes, and that none was found in the two end boxes.

In a bench hydraulic operation on Last Chance Creek, Klondike, a small undercurrent with cocoa-matting riffles had been put in after 400 feet of 2-foot sluices, with 12-inch grade, using block riffles. The undercurrent had given very satisfactory results, and a larger one was being constructed in addition.[a]

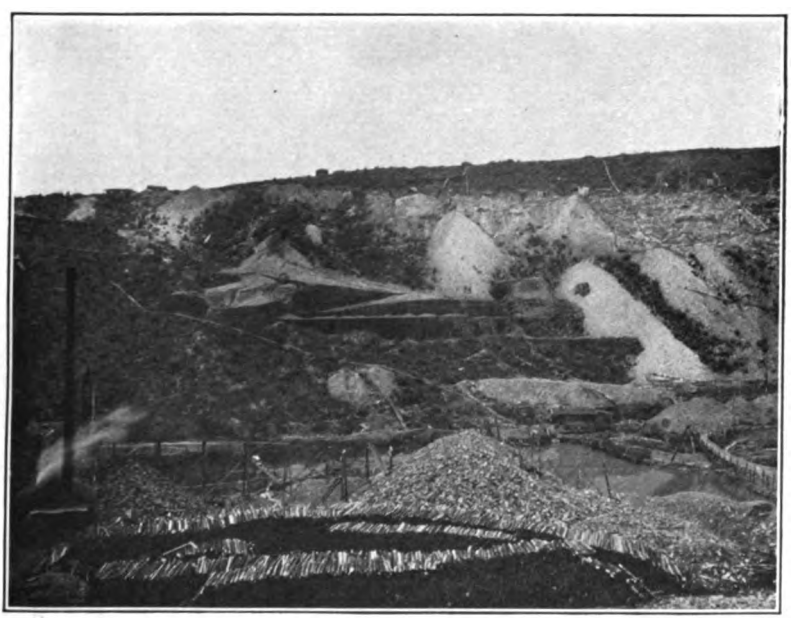
The above data indicate that where hydraulicking is possible in the Klondike, the gold-saving appliances are fairly adequate to the needs of the operations. As all hydraulic mining in that region is limited to ancient channels lying at an elevation of 200 feet or more above the present streams, water is exceedingly scarce, and sluicing methods must be adapted to this condition. These methods also depend on the necessity of impounding tailings on steep hillsides (see Pl. XXV, *B*), the high cost of labor ($7.50 a day), and of lumber ($80 per thousand feet), the necessity of making quick and frequent clean-ups, and the different economic ratio which obtains in recovering gold from small patches of rich gravel as distinguished from large bodies of low-grade gravel. When it is well established, therefore, that no great percentage of gold is escaping, it is likely that the extra cost of installing and maintaining complicated saving appliances would overbalance the increase in gold recovered. The use of drops in the sluices, and lessening of grade, might, it is likely, result in an increased saving, with no extra expense of maintenance, except in the wear of riffles at certain points in the sluices.

[a] See Bowie, A. J., jr.: A Practical Treatise on Hydraulic Mining in California, p. 231, for full description of undercurrents and the method of leading gravel to them from the main sluice.

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*A*. SLUICE BELOW ELEVATOR, OPHIR CREEK.



*B* RETAINING DAMS, BONANZA CREEK, KLONDIKE.

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In hydraulic elevator practice as pursued in various parts of Seward Peninsula, Alaska, short sluices are in use. Here, as elsewhere, a sluice is generally set in bed rock on a grade of 10 inches to 12 feet, or near this grade. On Ophir Creek, in the Council district, Alaska, the practice is to use from 10 to 12 boxes of 12 feet length, 24 inches wide and 16 inches deep, with wooden rail or pole riffles, shod with strap iron. This leads to the elevator sump, 10 feet deep. The position of the elevator with reference to the sluice below it is shown in Pl. XXV, *A*. The tail sluice following the elevator in the case specified is 28 feet higher than the head sluice. The tail sluice consists of five 24-foot boxes, 4 feet wide, and the practice is to give the first box either no grade, or a grade not exceeding 2 inches. The other boxes are graded from 2 to 5 inches successively, a 5-inch grade being retained for all below the fifth box, if more are added. On Ophir Creek, where there are six elevator plants in operation, iron riffles are generally used in the discharge sluice. A type of riffle which is used in the head box is made of railroad iron, cut in short pieces and set transversely in

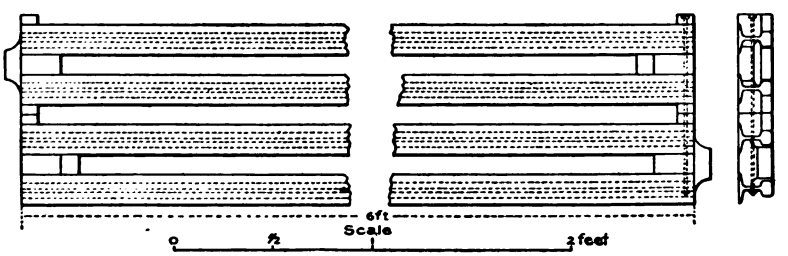



FIG. 32.—Rail riffles used in Seward Peninsula.

the box, forming a Hungarian riffle. Another kind in much favor throughout Seward Peninsula is composed of a set of T rails, in sets of 4 laid lengthwise (see fig. 32). These are made with a locking attachment, and are put in the sluice upside down. T angle-iron riffles, made in 1-foot square castings, laid in the sluice so that the slots set longitudinally, and with the flat side uppermost, are also very satisfactory and durable, and on account of their lightness facilitate the clean-up.

The proportion of gold caught in the head and tail sluices varies according to the practice. At Claim No. 2, below Glacier Creek, the gravel is run through 250 feet of iron boxes, only the two lower of which, next the elevator sump, contain riffles. These iron boxes are 10 feet long, 31 inches wide at the top, 27 inches at the bottom, and 8 inches deep, of a single bent sheet of iron, lapping 2 inches at the ends and fastened together with two bolts. The material slides easily through the cut in these, which are laid on 6-inch grade to the elevator. It is said that 50 per cent of the gold is caught in the last two of these, and 50 per cent is caught in the tail sluice after the elevator.

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In the elevator operations on Ophir Creek and on Basin Creek, in the Nome district, it is said that 75 per cent of the gold is caught before the elevator, and in one case no gold was caught below the first four boxes of the tail flume. The experience in Seward Peninsula has shown that the gold is for the most part rough, and even crystalline, and even when finely divided is saved with ease. One marked exception was seen at Anvil Creek, where a 500-foot string of boxes on 4½-inch grade caught gold for the entire length.

## TAILINGS.

It has been said that the most important part of the equipment of a hydraulic mine is the dump. It has been found that the amount of material which can be moved is governed primarily by the grade of the sluice boxes. Reference to table 11 (p. 139), shows that there is a fairly constant ratio between the grade of the tail sluice and the amount of gravel moved through it per twenty-four hours per miner's inch of water used.

Since it is a prime necessity in hydraulic mining operations that as large an amount of gravel as possible shall be delivered through the tail sluice and disposed of on the dump, it is evidently of the highest importance that a steep grade, 12 inches in 12 feet if possible, and on no account less than 6 inches to 12 feet, should be available for the sluice. It is manifestly impossible to secure this grade if the natural slope of the ground or creek bottom over which the material is run is less than that required for the sluices. The grade of the surface must in fact be more than that of the sluice, in order that there may be ample vertical space below the end of the lowest box for the tailings.

In hydraulic operations on bench gravels, as, for example, in the Klondike region, the conditions for obtaining grade for the sluices are more favorable than in any other hydraulic operation of the North. The gravels of the Klondike White Channel benches are easily moved after they are thawed. This is fortunate, as on account of the small amount of water available hydraulic mining on the benches would otherwise be impossible. The expense of keeping up dams for impounding tailings, however, is considerable. Naturally the barren tailings, consisting of white quartz stones of the size of paving stones, can not be allowed to wash and slide down to the creek bottom. Were this permitted, the creek miners would soon find their cuts flooded and their ground covered with thousands of tons of useless débris. Therefore impounding dams for tailings must be constructed of the strongest available materials, in order to resist the weight of the stones. The cost of building tailings dams of brush and poles, 20 feet high, in the Klondike, is $5 per linear foot. Retaining dams along Bonanza Creek in the Klondike are shown on Pl. XXV, *B*.

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In California hydraulic mines the dump, even after a series of drop-offs 25 feet in height, was sometimes in a canyon hundreds of feet vertically below the end of the sluice. The remarkable topographic conditions which allowed of such a phenomenal dump probably can not be found in another placer country, and certainly not in those portions of Alaska here considered. Even in California, however, it was often found necessary to distribute the dump by means of Y's near the end of the tail sluice. One such system is in practice on McKee Creek, Atlin, and has already been referred to. In hydraulic operations where 1,000 cubic yards or more a day are handled with low dump two carpenters have frequently to be employed at least half of the time in adding boxes to the tail sluice. If the dump be properly spread in delta form, the operation can be carried on in places where otherwise it might be impossible.

Where hydraulic operations are conducted in creek beds of low grade, below the so-called "sluice-box grade," or 6 inches in 12 feet, some expedient must be adopted to get rid of the accumulation of tailings below the end of the sluice. If the topography is such that the water runs off and only the solid residue of the tailings accumulates, the expedient is sometimes adopted of "piping" the dump away with an extra giant set in a convenient position for the work. This giant generally requires the services of one man, and, although used only a portion of the time, may be figured under Alaska conditions to add from 2 to 5 cents to the cost of handling the gravel. The efficiency of the plant is detracted from by so much power as is required to push the tailings out of the way. It can not be too strongly insisted on that when this or any other device is used to move or elevate the tailings, the strict principle of hydraulic mining is departed from. The use of the steam or horse scraper in removing the tailings of small plants is discussed on pages 70–72.

If the grade of the creek bed is lower than that necessary for the sluice, the tailings must be elevated and the water pumped from the pit. Mechanical elevators with the addition of a bed-rock drain are sometimes used, though not with success, so far as known. In one case on Mastodon Creek of the Birch Creek district the installation of a steam scraper for lifting the tailings from the hydraulic pit was contemplated, the water being handled by a bed-rock drain, which had been installed at great expense.

## THE HYDRAULIC ELEVATOR.

The hydraulic elevator is too well known to need elaborate description. The principle is the same as that of the injector. Water under pressure discharged through a nozzle set within a steel jacket creates a vacuum and causes water—about one-half the quantity used by the elevator—and accompanying solid material to rise to a height corre-

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sponding to approximately 10 per cent of the head under which the water acts. Many elevators have been used, and they all act on the same principle. One of the necessities is the constant admission of air with the tailings, which, by being compressed, aids in the elevating process. Those elevators are considered best which admit air most freely.

An exceedingly simple form of hydraulic elevator—the so-called "open" elevator—is in use in southern Oregon. The gravel is piped directly into an inclined box 8 by 30 feet in dimensions, which has a false bottom of punched iron plates. All the fines run back on the plank floor of the box to the undercurrent, the oversize falling to the tailings pile at the raised end of the box. The contrivance is a makeshift, but is said to be successfully used in the flat stream beds of southern Oregon.

A hydraulic elevator will sink a pit in a flat piece of ground containing no large stones. In starting new work on placer ground it is, in fact, the practice to sink the pit with the elevator. The portion of the hydraulic elevator shown in Pl. XXVI, *A*, is in position in the bottom of a pit 40 feet deep, on Glacier Creek, Seward Peninsula. This pit, which is 90 by 60 feet in dimensions, was sunk in ten days by a 7-inch elevator, smaller than the one shown in the picture, using 325 miner's inches of water at 360 feet head. At the claim next higher up the creek a similar elevator was in use, and a description of its operation will be of interest. Seven hundred and sixty miner's inches, under 330 feet pressure, were used in the operations. The water is afforded by the Miocene ditch, described on pages 123–126. The grade of Glacier Creek does not exceed 50 feet to the mile in its lower portion, where this property is worked. The gravel deposit, which is wide and 20 feet in depth to bed rock (see Pl. XXVI, *B*), can not be worked by the hydraulic method on account of the impossibility of disposing of the tailings. Therefore a long cut is ground-sluiced off to the depth of 6 or 7 feet below the surface. The elevator sump, which must be about 5 by 5 feet and 10 feet into the bed rock, is sunk in the bottom of the large pit. The elevator, which, with the head above given, lifts 36 feet, is set in position. For this ground a No. 1 elevator, having a 10-inch throat and using 4½-inch nozzle, is employed.

The hydraulic elevator, like the one shown in the photograph, is by no means simple. It consists of 15 large parts, some of them very heavy, and a number of rods, bolts, bands, and wooden staves. The cost of the one shown is approximately $750 in San Francisco, and the weight is 2,000 pounds. A pipe is led from the supply pipe to feed the nozzle of the elevator. It is connected to this by means of the ball joint. This joint, shown in the photograph, is exceedingly convenient, as it allows the pipe to enter the pit from one of several directions. Where the upcast pipe joins the top casting of the elevator it

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*A.* HYDRAULIC ELEVATOR IN PIT, GLACIER CREEK.



*B.* GRAVEL IN PIT, GLACIER CREEK.

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should be made to fit over and outside of this casting, so that there will be no leak. The casting should be rimmed outside to a depth of 2 inches. The jacketing of the nozzle is considered very good practice, as it prevents smothering with gravel. In the type of elevator here shown the advantage is claimed that the various parts, lining, backing, first section above throat, top section, etc., are separate and merely fit together, being held by a ring of wooden staves, as shown in Pl. XXV, *A*. This obviates the use of heavy castings. The upcast pipe is made of lap-welded steel, one-eighth inch in thickness, and either lead or flange joints can be used. In the plant described the pipe was in 18½-foot lengths and the joint was made by bolting together wooden blocks, 10 by 12 by 24 inches, with a half-round cut made to admit the pipe. The upcast pipe should be set at an angle of 60°.

By far the most important parts of the elevator as regards wear are the throat and the hood which receives the impact of the gravel in the

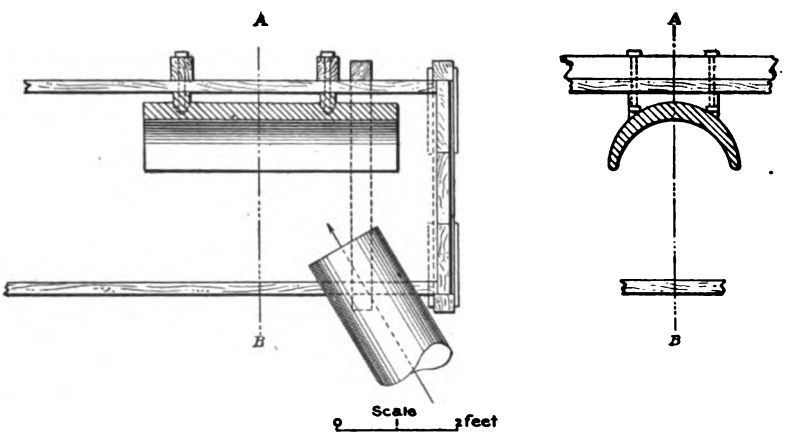



FIG. 33.—Hood in head box of tail sluice.

head box of the tail sluice above. These two parts are manganese steel castings, and if the gravel is very sharp and siliceous may wear out in one season. For the 10-inch elevator the throat weighs 400 pounds and the hood 600 pounds (price 16 cents per pound in San Francisco). The manner of setting the hood in the head box of the tail sluice is shown in fig. 33. The upcast pipe is laid against an inclined framework of four lengths of 2-inch plank 2 feet wide, and extends directly into the bottom of the tail sluice. (See Pl. XXVII, *A*.) Leading to the throat of the elevator directly above the nozzle is a sluice box, which conducts the gravel either from the boxes preceding it or from a bed-rock sluice, which is carried back on grade in the pit bottom as fast as the gravel is piped down. On Glacier Creek the gravel is led to the elevator in 24-inch iron boxes on 6-inch grade, with or without rail riffles. After leaving the discharge of the upcast pipe the gravel passes through eight or nine 36-inch boxes, with T-rail riffles. The first

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two boxes have 4-foot sides, reinforced inside and out with sheet iron, and are set high on a trestle to give the desired elevation for maintaining the dump. The grade is either 0 or 1 inch in 12 feet for the head box, 2 inches for the second, 3 inches for the third, 4 inches for the fourth, and 5 inches for the succeeding boxes. It is proposed to supplant wooden sluice boxes on this claim with iron boxes 8 to 10 feet long and from 2 to 3 feet wide, of one-fourth-inch sheet iron, weighing from 500 to 600 pounds each and costing from $15 to $20 in San Francisco. Five hundred and twenty miner's inches of water are used for the elevator and 240 inches are used through the 3-inch nozzle of the giant. The water is distributed from the supply pipe by 11-inch pipe to the two nozzles. By this arrangement 500 cubic yards of gravel can be handled in ten hours. It is said that the elevator is not handling over one-half the gravel that could be put through it if the larger amount could be moved to the throat. Experiments with scrapers operated by water power are in progress.

The practice here is first to run back with a narrow cut 250 feet up the creek from the elevator throat, then to come forward toward the elevator, breaking down the sides.

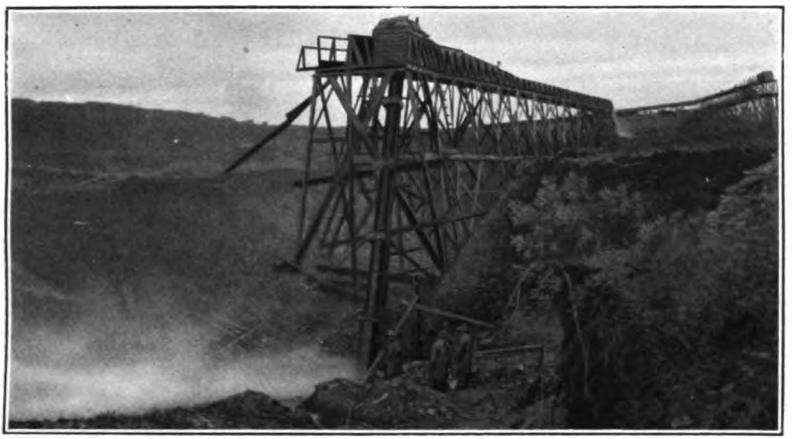
If the cut is 150 feet wide, 250 feet long, and 25 feet deep, a new set-up must be made every thirty-four days, assuming that the plant is run all the time at its full capacity. To make the new set-up of boxes and to build the trestle requires $400 worth of lumber and the labor of 5 men for five days. In addition, it takes the whole crew of the placer one day to take the elevator from its old position and place it again. The total extra expense is, then, nearly $1,000 in money and at least one full day out of the short working season each time that the elevator is moved.

In Seward Peninsula the handling of bowlders gives little trouble with the elevator. A 10-inch throat will take a 9¾-inch bowlder. It is not uncommon to see the men near at hand throwing small stones down at the throat of the elevator. This is because stones are jammed in the throat. The elevator for the moment is not clearing the pit, and the small stones artificially fed will act as small cannon balls to break the obstruction.

It should be noted that a very large amount of water is used for the elevator as compared with that used for the giant. It has been found most economical to distribute the water one-third to the giant and two-thirds to the elevator. If the elevator is too large for the water used, the employment of a choked nozzle or smaller nozzle will obviate the difficulty, while the larger throat does no harm. One of the most common difficulties with the hydraulic lift is the fact that it will choke if required to raise too much seepage or pipe water.

Elevator practice in hydraulic mining has been so limited in its application, and has met with so little success, that definite rules for

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*A*. HYDRAULIC ELEVATOR.



*B*. OPEN CUT WORKED BY TRAMMING TO BED-ROCK SLUICES.

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the guidance of the miner have not been formulated. The best that can be done is to cite examples of the results of actual practice and to enumerate the difficulties experienced. It is a common saying among users of hydraulic elevators that the machines will handle all the gravel that can be got to the throat.

The table for use in hydraulic-elevator operations is as given by the manufacturers:

TABLE 12.—*Water required in hydraulic elevators.*

| Number. | Water required. | Size of nozzle. | Size of throat. |
|---|---|---|---|
| | *Miner's inches.* | *Inches.* | *Inches.* |
| 1 | 300 to 500 | 3½ to 4½ | 10 |
| 2 | 500 to 750 | 4½ to 5 | 12 |
| 3 | 750 to 1,000 | 5 to 5¾ | 15 |

The above heads are those which are generally available in Alaska. The amount of water that can be handled successfully, in addition to that coming through the nozzle, does not in practice exceed one-third. If there is a large quantity of seepage water the excess must be taken care of by means of an auxiliary water lift. One of these is shown in position in Pl. XXV, *A*. It takes an 8-inch supply pipe, choked to 2-inch nozzle in 4-inch throat, with 70 inches of water at 100-foot head, to lift 80 inches of water 26 feet. This lift weighs 350 pounds and costs $140 in San Francisco. Whether such a lift is needed for continuous operation or not, it is convenient to have it at hand for assistance in temporary pumping of water from the pit during the time of clean-up and other periods when the main elevator is not acting. Double elevators are sometimes used in preference—a much more expensive installation.

All the hydraulic elevators seen in Alaska were of small capacity, carrying 10-inch throat or less. It should be remembered that the tables and estimates of percentage of lift to head are generally based on the assumption that the throat piece of the uptake pipe is double the diameter of the nozzle employed. In northern practice it is generally the experience that a smaller nozzle must be used than the theoretical size, and in consequence the lift is decreased.

The type of plant illustrated in Pl. XXVII, *B*, is not advisable except as a necessity, where surplus water from a head ditch is available. The gravel is shoveled from the cut by hand into cars which are trammed and dumped into the bed-rock sluice running to the elevator. The operation has no relation to hydraulic mining proper. The plant figured has a capacity of 700 cubic yards in twenty-four hours, the working expenses being no less than on a neighboring

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claim, with almost precisely similar geological conditions, where gravel was being handled by shoveling into 1¼-yard derrick skips trammed on trucks to the derrick, lifted to a sluice, and washed with gravity water. Now, grant that the cost of the derrick plant was $10,000 while that of the elevator plant was only $5,000. The water for the elevator, however, 500 miner's inches, represented one-fifth of that obtained by an elaborate ditch system, the proportionate charge of installation of which was $60,000. It is very unlikely that the life of either of these properties will exceed six years, and it can be easily seen that the amortization charge for cost of plant must be, less interest allowance, $17,000 in the elevator plant, as against $10,000 in the derrick plant.

It would be unfair to entirely decry the use of the hydraulic elevator in Alaska. On the other hand, it is a deplorable spectacle to see cases where expenditures of from $25,000 to $200,000 have been made to secure the use of water at a head, where the elevator is installed, and where it finally becomes apparent that loss will result in the operations because gravel can not be moved to the elevator in sufficient quantity.

To take a very typical Alaskan case, assume a body of material which, handled at the rate of 700 cubic yards a day, can be worked out in six seasons; that the section consists of 2 yards of muck and of 1½ yards of gravel which has a tenor of $3 per cubic yard. This material can be all handled by the hydraulic method at an expense of 50 cents per cubic yard, actual working cost, including superintendence. In order to make this hydraulic method available a ditch carrying 1,000 miner's inches of water at lowest stage must be built at a cost of $100,000. Let this cost include the hydraulic equipment. Simple interest charge on the investment and maintenance of ditch and plant will amount to $90,000 additional. Allowing nothing for purchase of property, the five annual payments to amortization of plant fund will amount each to $38,000. Allow one hundred days each season actual working time. Then the amount per cubic yard which must be added to cover payment to the sinking fund will be 0.542 cents per cubic yard, or a total of $1.042.

This cost will not be regarded as extreme by those who have had experience in similar undertakings. The operator has a choice of mechanical plants, by using one of which he could work the ground with great economy. In other words, the use of the hydraulic elevator in Alaska frequently defeats the object for the attainment of which the hydraulic method of mining is employed.

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## DREDGING.

### INTRODUCTION.

The opportunities for gold dredging in the far Northwest are not by any means numerous. Perhaps no part of the gold-mining industry is dependent on so many conditions for its financial success as the dredging of auriferous gravel deposits for gold. Some years ago, in connection with Mr. J. B. Landfield,[a] I published a review, setting forth the geological conditions which are necessary for the success of gold dredging, the consideration of which is frequently neglected by those contemplating the installation of dredges. The portions of that paper which deal with the present case are here quoted. The prime consideration is that conditions of a peculiar character are a necessary accompaniment of the values in any locality where it is proposed to win gold by dredging. Recent experience has proved that the greatest attention must be given to topographic and geologic conditions in the country in which the enterprise is to be inaugurated, otherwise success in the operations is not to be looked for. The following explanation of the conditions necessary for dredging is therefore pertinent:

Taking the country about Oroville, Cal., as the best example in the United States, let the geological conditions be considered. To the north and east the erosion of a vast extent of mining country, whose rocks are penetrated by gold-bearing veins, has contributed little by little through geologic ages to the mass of detritus now occupying the bed of Feather River. The wearing down of mountains, originally very much higher than at present, through a vast amount of time has caused the formation of a valley of extraordinary width but of no great depth. The massing of stream detritus is also responsible for a decrease in the gradient and a slowing down almost to a topographical equilibrium of the formerly swift current of the river. The stream, unable under these conditions to cut its way by virtue of the material which it carried in suspension, has for a long time been depositing its load, filling its wide valleys with sand and gravel, together with the less destructible of the metallic particles, and notably gold. Geologically speaking, the rate of deposition of the river's material may be said to be on the increase and the current of the water, still of considerable velocity, to be greatly lessening in swiftness. Later in its geologic cycle Feather River will doubtless assume, on a smaller scale, the present character of the Mississippi, forming oxbow curves, cut-offs, and, as it were, losing its way among constantly shifting sand bars.

The accompanying residual gold, as it travels to a greater and greater distance from its original source in the veins of the mountains, becomes more and more finely divided, even to microscopic dimensions, and increases in purity, and the degree of evenness with which the particles are distributed in the gravel becomes a phenomenon of constantly increasing definiteness and importance.

Such a set of conditions as that obtaining on Feather River is the exception rather than the rule in the western part of the United States, and even in California. The above explanation has been entered into in order to present in some measure the reasons why, on the California river referred to, the conditions are not only favorable but eminently suited to gold dredging. Shallow gravels—that is, those less than

[a] Purington, C. W., and Landfield, J. B., jr., The gold-dredging fields of eastern Russia: Eng. Mag., vol. 22, 1901, pp. 398–407.

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40 feet in depth—are an essential in dredging enterprises.[a] Thus broad rather than narrow, gorge-like valleys must be sought. Bed rock of a soft, decomposed character, which can be easily cut into by the dipper or bucket of the dredge, is a necessity, since placer gold, by virtue of its gravity, often sinks from 1 to 2 feet into the crevices of the rock underlying. It is hardly necessary to state that the amount of gold increases in geometrical ratio the lower it lies in a given bed of gravel. Thus old rather than young valleys are favorable for dredging.

Additional reasons of great weight why geologically old valleys should be looked for are that the size of bowlders is greatly decreased, gravel becomes by long abrasion uniform in size, the angularity of the fragments disappears, and a bed of pebbles, round and easily handled, is the result.

The even distribution of the gold which, as mentioned above, is an invariable accompaniment of old and wide valleys, is a point in favor of this sort of mining, looked at from the standpoint of a business enterprise. At the same time it is evident that the finely divided state in which such gold is found necessitates the highest skill in recovering it. For example, at Oroville, although some of the operators are saving gold the subdivision of whose particles is almost microscopic, it is thought with good reason that a considerable percentage of values is lost in the water used for the washing.

The conditions on Yuba River in California are, from the dredging standpoint, as favorable as those at Oroville.

The conditions above mentioned as important to the success of gold dredging should be taken account of as much by the men who contemplate installing dredges in Alaska, as in any other part of the world. While it is true that there are in Alaska broad valleys, such as those of Yukon River and its larger tributaries, and that they have been found to be to a certain extent gold bearing, yet peculiar and formidable conditions serve as a barrier to the exploitation of these streams by dredging. A remarkable illustration of this fact came to my notice during the last summer. In a small island facing the settlement of Eagle, in the interior Yukon country, a shaft sunk through rolled stream gravel to a depth of about 40 feet in winter penetrated perpetually frozen ground until near the limit of its depth. At this point an underflow of water was encountered so strong as to prevent further prospecting. It was said that good values in gold, even up to $1 to the yard, were found in sinking this shaft. If this be true it would imply that considerable areas of the underlying immensely wide gravel flats of Yukon River are gold bearing. Under other conditions portions of the ground might be found workable by gold dredges. Experience has shown that in Alaska the permanent frost which exists in much of the river country renders the exploitation of the gravel by ordinary mechanical means absolutely impossible. It is the opinion of those who have attempted the dredging of frozen gravel in the Klondike that, while the devising of a dredge strong enough to dig frozen gravel is not impossible, the undertaking has not yet reached

[a] Since the above was written the enlarging and strengthening of dredges has resulted in successful digging (on Yuba River, California) to the depth of 60 feet. It should be noted, however, that the upper 25 feet of the Yuba gravel section consists of loose tailings.

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even the experimental stage. In the interior the cost of dredging unfrozen ground is 40 cents per cubic yard, while the dredging of frozen ground by thawing ahead of the dredge with steam points requires an expenditure of 40 cents additional. It will be recognized by those familiar with dredging that such a cost is prohibitive of the exploitation of the average dredging gravels.

River-bed gravels seldom average over 20 cents to the cubic yard in gold, locally enriched area from side tributaries necessarily being excluded. It has been frequently stated by engineers that the average tenor of the Oroville gravels is not above 15 cents to the cubic yard. I see no reason to believe that the gravels of the Alaska rivers, the Yukon, Tanana, Koyukuk, Kuskokwim, and their larger tributaries should be any higher. It is likely that only in very restricted areas will the tenor in gold of these streams be as high as 15 cents. It should be distinctly understood that Solomon River, Snake River, and streams of similar size in Seward Peninsula are not properly called dredging streams. They do not by any means fulfill the conditions implied in the foregoing geological description. While it is undeniable that in certain isolated cases streams having the character of Solomon River may be profitably dredged, the enterprise must be considered as lying outside the legitimate province of the gold-dredging industry as developed in California and New Zealand.

A recent study of the dredging fields of California has led to the conclusion that while dredging is possible to a greater depth than formerly (60 feet in Yuba River), there has been little reduction in the general costs of work. Eight cents per cubic yard is the lowest cost which may be safely counted on at Oroville, the principal field.

No special devices have been put into practice for breaking up cemented gravel, and some of the dredgers at Oroville are compelled to use powder to shake the bank in front of the dredge. Such practice would have no beneficial effect in handling frozen gravel. The use of hydraulic nozzles attached to the ladder frame at the lower tumbler seat has several times been suggested by engineers for assistance in thawing frozen gravel as the dredge operates.[a] Experience in hydraulicking frozen bench gravels in Alaska has proved that such a device would be of no avail, since it is mainly the action of the sun and not that of the water which thaws the gravel face. The possible method of steam thawing is to drive long pipes from the surface into the ground ahead of the dredge (the practice in Bonanza Creek in 14-foot ground). The cost of this would probably be prohibitive when the depth of the ground exceeds 15 feet.

The only manner in which heat can be applied directly to the part of the gravel face where the buckets are digging is by means of elec-

[a] Levat, E. D., L'Or en Sibérie orientale.

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trically heated water thrown against the bank. The fact that hydraulicking with water heated to 50° and applied directly to the face through a nozzle in Klondike drifting operations is remarkably effective in thawing frozen gravel suggests possibilities in regard to dredging. This possibility is extremely remote, but might under certain circumstances be applicable where the dredge is operated by electric power generated by water under head.

The fact the dredge is the only appliance used in placer mining which transports its sluices and continually provides new room for its tailings renders it attractive in the consideration of the shallow northern placers.

In Seward Peninsula there are some river deposits which contain gold sporadically distributed and in which frozen and unfrozen areas alternate. Extensive prospecting has resulted in the discovery of a certain amount of ground which appears to warrant the installation of dredges of special design. More of these areas may be found, and it is probable that some of them may be in the interior. It is not believed that dredges can be operated successfully in any of the area included in the South Coast provinces, as there the geological conditions are almost the exact opposite of those outlined at the beginning of this section.

### DESCRIPTION OF OPERATIONS.

Notwithstanding the difficulties encountered in the interior of Alaska, the possibility of dredging in this field under certain favorable conditions is not to be denied. A small dredge for prospecting purposes was being operated cheaply in Stewart River in the Yukon Territory, not far from the international boundary, during the season of 1904. It subsequently operated in Klondike River. This dredge has 39 open connected 2¼-foot buckets, and handles 750 cubic yards in twenty-four hours. It digs to 30 feet, and in Stewart River very little frozen gravel was encountered. A crew of 6 men is employed and the daily working cost alone is said to be 7 cents a cubic yard. The hull was built at White Horse, of 4-inch planks of imported Vancouver fir, and cost $5,000.

A complete description of this dredge has been published by the designer, Mr. A. W. Robinson.[a]

A dredging installation was also visited on Gold Run, in the Atlin district of British Columbia. The power plant was situated on Pine Creek, 5 miles below the dredge. A flume and ditch line 1½ miles in length supplied 1,500 inches of water, at 187 feet head, to 2 Victor turbine wheels of 500 horsepower each. It was said that 80 per cent of this efficiency was available at the dredge. The current was delivered at 1,100 volts to the transformer and this was stepped up to

[a] The Stewart River gold dredge: Canadian Mining Institute, March 4, 1903.

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*A.* SINGLE-LIFT DREDGE, 40-FOOT GROUND AT ATLIN, COARSE GOLD.



*B.* BUCKETS, ATLIN DREDGE.

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22,000 volts before its conduit over No. 6 copper wire 3-phase system to the dredge transformer, where a step-down to 500 volts was made. The turbines have 24-inch intake and 30-inch discharge, and the gates weigh 2½ tons each. The water is available from April 1 to November 15. The power plant cost $50,000, not including an outlay of $10,000 for a 5-mile pole line, 3 copper wires, and 20 telephone wires.

The pole line was built by contract requiring that the poles should be 6 inches in diameter at top, 24 feet above and 5 feet below the ground, and that timber should be cut for a width of 40 feet, all at a cost of $2,250 for 7 miles.

A general view of the dredge is shown in Pl. XXVIII, *A*. The cost, installed on the ground, was $200,000. It is of the close-connected, 3-foot bucket, single-lift type, arranged with trommel and pivoted sluice box, and tables carried on separate float. This type of dredge was considered necessary on account of the presence of coarse gold in the deposit. That by all dredging engineers the occurrence of coarse gold is not thought prohibitive of the use of the stacker dredge is apparent from Mr. Hutchins's remarks on this subject (see pp. 173–190). The arranging of the entire tail sluice to turn in an arc, operated by stern lines, permits the distribution of the dump. The system of digging is against a spud and not a headline. Operations had only begun when the dredge was visited; its estimated capacity is 2,500 cubic yards in twenty-four hours, digging to an average depth of 44 feet. The dredge is equipped with 5 motors, and a total of 200 horsepower is used. The total weight is 400 tons.

The hull was built in a pit on the ground, of Vancouver fir, and afterwards floated in the pond shown. It has a draft, loaded, of 3½ feet, and is 90 by 36 feet in dimensions.

The winches are controlled by levers directly above in the pilot house on the starboard side of the upper deck. The 7 drums operate the 4 side lines, main ladder line, and 2 spud lines.

The digging ladder is 90 feet long, 3 feet wide and 2 feet deep in the center, and is braced by steel trusses. The tumblers are of pentagonal form and of steel, with manganese steel plates riveted on, with 8-inch shaft. There are 96 buckets that hold 3 cubic feet each, have the shape shown in Pl. XXVIII, *B*, and are equipped with manganese steel lips, pins, and bushings. As shown by Pl. XXVIII, *A*, a bowlder weighing 1,500 pounds rode one of the buckets and was taken off on the upper deck. The buckets will dig 40 feet in front of the bow, and a bank 8 feet above water can be handled. The rate of wear in bucket lips had not been determined. A nozzle is used to clean the buckets as they pass the upper tumbler. No save-all is used. The sprocket wheels and chain are of steel, the diameter of the upper wheel being 10 feet.



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The motors are of the following rated capacity:

| | Horsepower. |
|---|---|
| For digging | 100 |
| For 10-inch centrifugal pump | 50 |
| For 6-inch centrifugal pump | 20 |
| For screen | 20 |
| For raising ladder and operating lines | 30 |

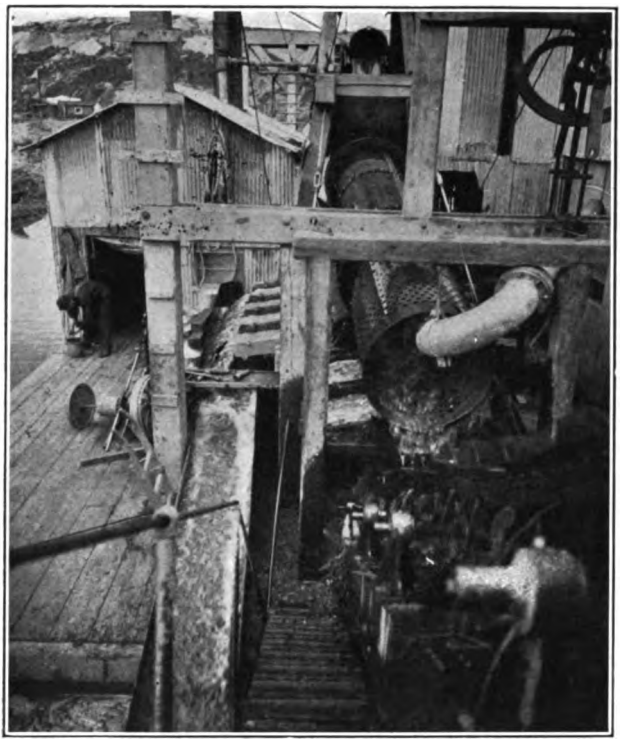
The gravel is raised 27 feet above the water. The trommel is 5 by 12 feet on 8 per cent grade, punched with holes that are 1½ inches in diameter in the upper plate, 4½ by 7 inches in the middle plate (enlarged from smaller size), and 4-inch holes in the lower plate. Thirty-five per cent of the material is oversize and is dumped directly from the end of the trommel into 2 side chutes overboard. The trommel has 6-inch spray pipe, supplied by the 6-inch pump with water under 40 pounds pressure. It is estimated that the trommel plates will last one season.

From the trommel the undersize falls directly to a sluice connected by means of a pivoted box to the main sluice in the auxiliary float. This sluice is 4 feet wide, 120 feet long, and 2 feet deep, is of steel, has a grade of 8 per cent, and is provided with Oroville Hungarian riffles and grizzlies to allow the material to pass to undercurrent tables, which have an area of 1,000 square feet (see p. 195). The dump of the main sluice is 8 feet above the water. Two hundred pounds of quicksilver are kept in the sluice and tables.

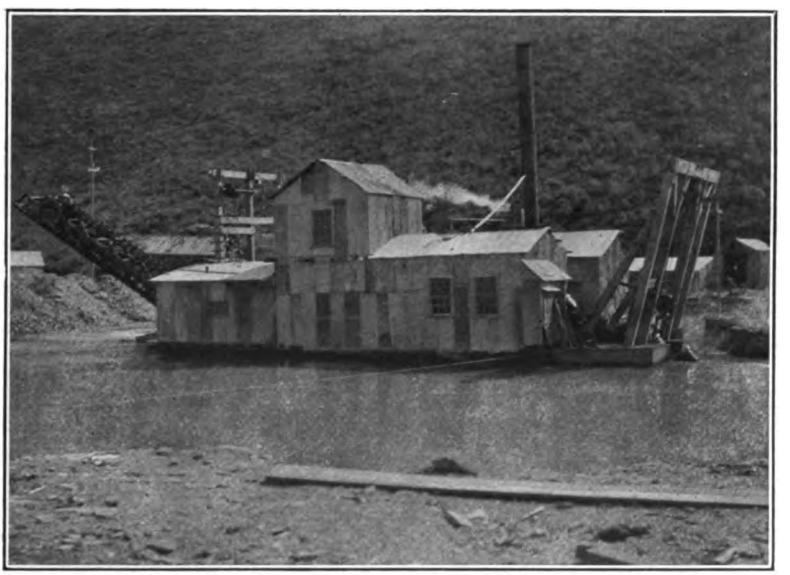
The cost of dredging at this plant is estimated at 8 cents per cubic yard for the capacity above given, only actual labor, supplies, and superintendence on the ground considered.

A dredge of the New Zealand type was operating on Bonanza Creek in the Klondike district. It is shown in Pl. XXIX, *B*. The boat had been in service for several years, having been first installed on Lewes River. It had then been towed and hauled by cables down Yukon River to the mouth of the Klondike and then taken apart and reerected on Bonanza Creek, where its operations have continued during the open months since July 1, 1903. A crew of 24 men operate the dredge and thaw the gravel in front of it. The thawing is done by means of 11-foot pieces of gas pipe, 12 in number, driven vertically into the ground. The bed rock here is a sericite-schist and the dredge is said to clean it well. The capacity of the dredge working under present conditions is 500 cubic yards in twenty-four hours. The bucket line is equipped with thirty 3¼-foot buckets, open connected. The ladder is 50 feet in length and will dig 28 feet below the surface of the water. At present the dredge is digging to a depth of 14 feet and 8 feet in front of the bow. The stacking ladder carrying a steel-bucket conveyor is 38 feet long, and carries all material over 1½ inches in diameter, the size of the largest holes in the trommel. The lips of the digging buckets are of manganese steel and last four

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*A*. TROMMEL AND GOLD-SAVING TABLES, NEW ZEALAND TYPE, BONANZA CREEK, KLONDIKE.



*B*. NEW ZEALAND DREDGE, BONANZA CREEK, KLONDIKE.

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months in use. New buckets cost $22 landed. The dredge digs on a 1-inch headline with five-eighths inch side lines, no spuds being used, and appeared to dig the gravel very satisfactorily after it was thawed. There is not over 2 per cent of the gravel which is over 18 inches in diameter. The hull is 71 by 30 feet in dimension and draws 4 feet of water; 55,000 feet of Oregon fir was used in its construction. The bow and ladder gauntrees are 15 feet high and are built of timbers 12 inches square. The dredge is operated by steam power. One vertical engine of 50 horsepower operates the dredge exclusive of the winches, which employ a separate 10-horsepower engine. The boiler carries 110 pounds of steam and in twenty-four hours burns 3 cords of native spruce wood, which costs $10 a cord. The winches are on the starboard bow side, the winchman's position being on the lower deck.

Since the trommel was built its length has been increased and is now about 15 feet, with $\frac{9}{16}$-inch holes in the upper plate and $1\frac{1}{2}$-inch holes in the lower. The trommel was extended so that none of the nuggets, which are worth from $12 to $200, would be lost. The trommel distributes the fines to 8 tables, 42 by 30 inches in dimensions (see Pl. XXIX, *A*), the distribution being regulated by iron gates. The tables, fitted with cocoa matting and expanded metal, have a grade of $1\frac{1}{2}$ inches to the foot, and are followed by 2 sluice boxes 20 feet long by 2 feet wide, with angle-iron riffles, which discharge at the stern, as shown in the illustration. An inevitable difficulty with the dredge is the banking up of this material at the stern. Three thousand gallons of water per minute are pumped by a 10-inch centrifugal pump. The tables are cleaned up every day; sluices, once a month. The season for operating is from May 15 to October 1. It is understood that the dredge was successfully operated during the season of 1904 on ground which had been previously drifted.

The cost of the dredge laid down originally in Lewes River was $125,000.

A shift sheet used in this dredge, devised by Mr. J. M. Elmer, is here appended and may be of interest to those engaged in or contemplating dredging operations.

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*Shift sheet of Lewes River Mining and Dredging Company.*

Date, ———.
Number of shift, ———.
Winchman, ———.

| Lost time. | Materials used. | Remarks. | Hours. | Minutes. |
|---|---|---|---|---|
| Ladder and bucket line | | | | |
| Stacker | | | | |
| Winches | | | | |
| Screen | | | | |
| Pumps | | | | |
| Lines | | | | |
| Clean ups | | | | |
| Oiling | | | | |
| Boiler | | | | |
| Condenser | | | | |
| Line shaft | | | | |
| Engine | | | | |

Character of ground, ———. Total lost time, ———. Depth of ground, feet, ———. Total running time, ———.

Foreman, ——— ———.

No dredging operations were in progress in the interior of Alaska during the summer of 1904.

In Seward Peninsula two dredges were operated in Solomon River and two land dredges were in operation in the vicinity of Nome, while another dredge was being constructed in Snake River near Nome, and a dredge was operating in a small way in Niukluk River, 1 mile above Council.

About one-fourth mile east of the town of Nome a small land dredge was operating on beach sand in the maritime strip. The section on which the dredge operated was 12 feet in thickness, and consisted of 6 feet of beach sand, 4 feet of clay, 2 feet of gravel, and 2 feet of underlying broken schist.

The dredge, which cost $5,500 in Seattle, was operated with a 6-horsepower gasoline engine. In addition, power was furnished to a centrifugal pump, which had the suction pipe led 60 feet out into the sea water. Eighteen gallons of gasoline, costing 40 cents a gallon, were burned in ten hours. The dredge was mounted on trucks surmounted by a turntable, allowing it to turn on a circular track. The average capacity was said to be 200 cubic yards a day. This represents one of the many attempts which have been made to dredge the Nome beach sands, none of which, so far as known, have met with any success. This material is unfrozen, but many difficulties are encountered. Storms which render the beach uninhabitable are causes of long delay, and the attempt to pump the sea water is a cause of constant trouble on account of the seaweed and wreckage which clogs the screen.

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A small land dredge running on a 40-foot track, and digging a canal beneath for the purpose of laying a long bed-rock drain, was operating on Bourbon Creek, one-fourth mile north of Nome. The work was in an experimental stage, and a large dredge of the same type, of 500 cubic yards daily capacity, was under construction.

A floating dredge of the dipper type, with sluices arranged on a separate hull, was under construction in Snake River, one-half mile from Nome, but the data relating to it are not available for publication.

A small bucket dredger so arranged that the digging ladder can turn through an angle of 20° has been operating in Solomon River, 3 miles north from the coast for the last two seasons.

In the operations of 1903 a 60-foot width of the channel of Solomon River was worked and was found to be unfrozen; the gravel averaged 5 feet in thickness and rested on schist bed rock. The tenor is said to have been $1.13 per cubic yard. The greatest thickness encountered from the surface of water to bed rock was 12 feet. One and one-half feet of the schist bed rock was taken up by the dredge. The bed rock is generally soft, but has hard reefs. The largest stones found were 1 foot in diameter. The dredge was operated by 5 men on 2 shifts, the amount of running time being from twelve to twenty hours out of the twenty-four. The men are said to have made a profit, paying a royalty of 25 per cent on the output. The dredge is of 16-horsepower capacity and handles an average of 150 cubic yards in twenty-four hours. The operations consume two to three cases of gasoline a day, the average for fuel being $12.50. The total expense is figured at $30 a day. The experience with the pay is that the ground is very spotted, being in places rich and in places barren. There are 32 buckets of 1 cubic foot capacity on the ladder. A cut of 30 feet across is made in one setting. The ladder is made of 4-inch cast-iron pipe and can be lengthened by adding pipe and buckets. In 1904 the dredge was being operated by 2 men on a shift, one man running the winches, and one man attending to the engine and picking out the large bowlders and throwing them overboard. The bucket lips are made of tool steel.

The sluices into which the buckets dump directly are fitted with punched-iron screen of the "Caribou" pattern, described elsewhere, followed by Hungarian riffles. The sluice is 64 feet in length, 23 inches wide, and 12 inches deep, with a grade of 15 inches in 12 feet. The end of the sluice is 3 feet above the deck, and extends 6 feet beyond the end of the boat. Quicksilver is used in the upper boxes. Seventy-five per cent of the gold is caught in the first 6 feet, and the balance in the next 8 feet. The tailings are frequently panned, but no gold found.

The description of this dredge, the cost of which should not exceed $25,000, laid down, is given in detail, as it is reported on good author-

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ity to have been successful in its operations. It presents a strong confirmation of the views expressed by Mr. Hutchins concerning the advisability of installing prospecting dredges for Alaska practice.

During the season of 1903 and 1904 a dredge of the dipper type was operated in Solomon River, near the one above described. The dredge was constructed originally with a stacker, but this system was abandoned and a separate hull was built on which a hopper and sluice were erected.

The dredge cost $33,000 on the ground, and weighs, barges and all, 400 tons. It is equipped with one yard dipper, which digs three-fourths cubic yard of material each time on an average. During 1904 the dredge was in operation fifty days of twenty hours each, and handled 21,000 cubic yards, or an average of 420 cubic yards a day.

The ground dredged is 9½ feet in average depth, and was all handled by the dipper. No permanent frost was found in the river bed, but the annual frost did not leave the ground until July 15, delaying the commencement of operations until that date. Thirty days at the end of the season were lost on account of the breaking of the main cable operating the dipper, and there was no chance to repair it.

The experiences with the ground in this dredging operation were especially interesting. It was found that in places the gravel in the river itself was frozen all summer. On July 20 there were 7 inches in depth of frost within 2 feet of the surface. This disappeared with the first heavy rain. The dipper cleaned the bed rock successfully where it was black schist. Where the bed rock was limestone the ground was drifted in the winter with much more satisfactory results than the dredging gave.

The dredge employed in the two shifts seven men, at $7 a day, and one man, at $9.50 a day, without board. In twenty hours 3 tons of coal, costing $26 per ton, were consumed.

The cost of dredging in 1904, including repairs to and maintenance of plant, was 50 cents per cubic yard. As in the case of the small dredge, the pay over a width of 200 feet, which was worked in places, was found to be spotted, varying from 30 cents to $12 to the cubic yard.

It is said that the clay in the gravel prevented the water from sluicing gold from the bottom of the dipper, and tests showed that a saving of 95 per cent was made. The sluice was paved with Hungarian riffles, and quicksilver was used.

The general opinion expressed by these operators was that dredges having a capacity of not to exceed 1,000 cubic yards daily will pay in Solomon and similar rivers of Seward Peninsula if operated by electricity generated from a central water-power plant. The employment of gravity-sluicing water was made a necessary condition. While

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this is possible, it should be borne in mind that the employment of gravity-sluicing water on a dredge entails numerous and largely untried difficulties.

Some of the special difficulties actually experienced in the operations above described were distance from any repair shop, sudden rises of the river after two days' storm that prevented persons from crossing and endangered the dredge, and repairs which were necessary at the beginning of the season, and which included chopping ice out of the inside of the hull.

The dredge shown on Pl. XXX, *B*, in Niukluk River, was operating only in prospecting work during the season of 1904. It has 5-foot buckets, open connected. Its rated capacity is 2,000 cubic yards in twenty-four hours, but the actual capacity can not be given. The dredge was fitted with a rubber belt conveyor for the stacker. This is said to give much trouble, as when it begins to freeze at night in September the belt continually slips. It was said that in previous operations the dredge in ten hours used 5 cords of spruce wood, costing $12 a cord, and handled 800 cubic yards of material. Eight men were employed at $7 a day, gross. In the Niukluk River banks the bed rock, which is schistose limestone, is 10½ feet below the surface, and is overlain by 1 foot of moss or willow roots, 2½ feet of sand or muck, and 7 feet of rounded river wash mixed with angular limestone fragments. Willows grow on the unfrozen ground and moss covers the solidly frozen ground. No regularity in the distribution of the two is apparent.

The success of dredging operations in the Niukluk appears to be extremely problematical. So far as the physical nature of the gravel goes, no difficulty should be experienced. Frozen areas, hard bed rock, uneven depth, and irregular distribution of the alluvial gold are, however, serious if not insurmountable obstacles to the success of a dredging operation which in a superficial examination of the ground may appear attractive.

## COST OF DREDGING.

It is manifestly impossible to give detailed statements of operating expenses in a work of this character, especially when dredging has been conducted in a desultory fashion and for a limited period. The costs given on page 38 include a certain amount each year for the amortization of the plant and the ground. Bearing this in mind, those having the slightest familiarity with the subject will probably admit that the figures, namely, 49 cents per cubic yard for unfrozen, 80 cents for frozen ground in interior Alaska, and 43 cents per cubic yard for Seward Peninsula, are not excessive.

For purposes of comparison there is given the following statement of the cost at Oroville, Cal., quoted in the Mining and Scientific Press, February 18, 1905, from the report of the Oroville Dredging and

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Exploration Company to the stockholders for the year ending December 31, 1904, by F. W. Bradley, president. The figures given represent merely operating expenses, and do not include allowance for depreciation of the plants and of the ground. It should be remembered, however, that even adding these items of expense to the operating cost per cubic yard the number of yards handled per season is so large, as compared with that possible in northern operations, that the total California cost is not greatly increased. Eight cents per cubic yard is believed to be a safe estimate for the present total cost of gold dredging at Oroville.

The table of lost time in the following quotation is especially interesting as showing that even under the favorable California conditions the actual dredging time of a presumably representative dredge amounted to only 67.2 per cent of the whole.

DREDGING AT OROVILLE, CAL.

Our No. 1, or $45,000 dredge, made the following record:

| | |
|---|---|
| Cubic yards dredged | 493,150 |
| Gold yield per cubic yard, $0.1232; operating costs, $0.0562; operating profit, $0.067, or | $32,905.79 |
| Improvement, taxes, insurance, legal, and all other working expenses (except construction of No. 2 dredge) | 7,166.88 |
| Surplus | 25,738.91 |

Our No. 2, or $75,000 dredge, should be ready to begin work next month (January, 1905). Figuring on the data now available, the two dredges should make the following average annual record:

| | Dredged. | Operating cost. | Probable yield. | Surplus. |
|---|---|---|---|---|
| | *Cubic yards.* | *Per cu. yd.* | *Per cu. yd.* | |
| Dredge No. 1 (first cost $45,000) | 520,000 | $0.0530 | ..... | ..... |
| Dredge No. 2 (first cost $75,000) | 780,000 | .0500 | ..... | ..... |
| Total or average | 1,300,000 | .0512 | ..... | ..... |
| Improvements, taxes, and all other working expenses | ..... | .0088 | ..... | ..... |
| Total | ..... | .0600 | $0.095 | $0.035 |

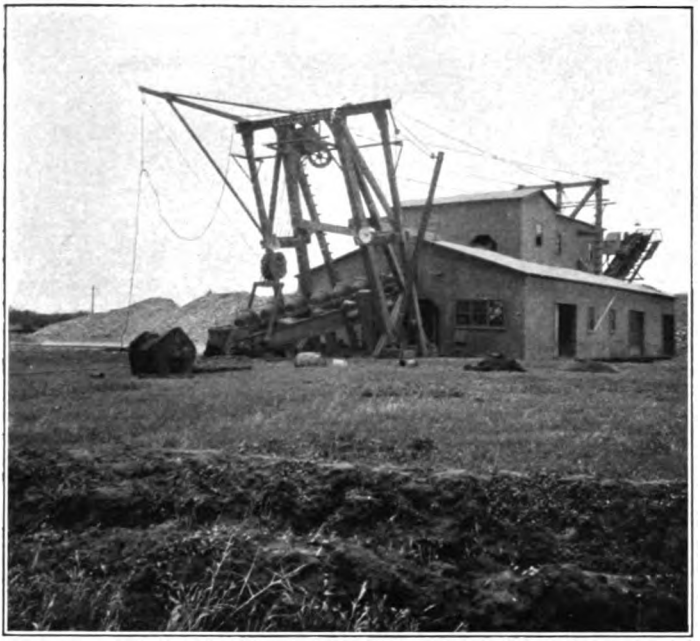
Or a yearly surplus of $45,500. Our prospect information indicates that after rejecting that portion of our land of doubtful value the property should have a life of from thirteen to fourteen years at the above estimated rate of dredging.

C. H. Munro, superintendent, makes a detailed report of the company's operations, from which the following is taken:

*Extraction.*—The prospect value of the area dredged, based on the average value of the holes in and near the dredged area, was 16.64 cents. The extraction table herewith attached, which is computed on these figures, makes the extraction 74 per cent of the prospect value.

The extraction amounted to 76.37 per cent of the prospect value, based on the proportional or fractional areas as influenced by each prospect hole.

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*A.* DREDGE OF NEW ZEALAND TYPE AT OROVILLE, CAL., LEGGETT NO. 3.



*B.* BUCKETS, DREDGE AT COUNCIL.

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It would therefore be fair to call the extraction 75.18 per cent of the prospect value, which is the average of the two methods of computation above referred to.

During the year just ended, Biggs No. 1 dredged 11.85 acres, handling 493,150 cubic yards, which yielded a gross bullion return of $60,738.52, or an average yield of 12.32 cents per cubic yard, as compared with a gross bullion return of $36,525.25, or an average yield of 8.45 cents per cubic yard for 1903.

*Costs.*—The operating cost has been 5.62 cents per cubic yard, and the total cost, including all improvements, repairs, taxes, insurance, legal, office, and other expenses (excepting Biggs No. 2 construction account), has amounted to 7.06 cents per cubic yard.

Comparing the capacity of the dredge and the cost of operation for 1904 with 1903, the capacity has increased from 39,551 cubic yards per month to 41,096 cubic yards per month, while the cost of operation has decreased from 6.48 cents per cubic yard to 5.62 cents per cubic yard, and the total expense from 7.71 cents to 7.06 cents per cubic yard.

The bullion yield has increased from 8.45 cents per cubic yard to 12.32 cents per cubic yard.

*Repairs.*—Aside from the ordinary repairs on the dredge, a new revolving screen was installed at a cost of $1,600, and the 1-horsepower motor used for priming the water pumps and cleaning up was replaced by a 3-horsepower motor at a cost of $127.55.

*Flume repairs.*—During the floods last February 500 feet of the flume and trestle were washed away. The rebuilding of the flume and trestle and repairs at the pump station cost $357.40.

*Improvements.*—The blacksmith shop equipment has been enlarged at a cost of $547.45 by installing a 5-horsepower motor, with transformer, a forge, blower, emery wheels, grindstone, and small drill press.

*Biggs No. 2 construction.*—The hull of Biggs No. 2 is completed and the dredge was floated the first of the year. The contractors are now installing the machinery, and the dredge will probably be ready for operation about the middle of February, 1905.

*Bullion table.*

| Month. | Cubic yards bank measurement dredged. | Bullion yield. | Operating expenses. | Yield per cubic yard. | Operating cost per cubic yard. | Operating profit per cubic yard. |
|---|---|---|---|---|---|---|
| | | | | *Cents.* | *Cents.* | *Cents.* |
| January | 20,340 | $3,120.87 | $2,677.00 | 15.38 | 13.16 | 2.22 |
| February | 32,000 | 3,408.59 | 2,205.07 | 10.65 | 6.89 | 3.76 |
| March | 41,160 | 7,732.62 | 2,418.94 | 18.78 | 5.88 | 12.90 |
| April | 50,760 | 9,600.10 | 1,854.69 | 18.91 | 3.65 | 15.26 |
| May | 47,700 | 8,072.17 | 2,233.41 | 16.94 | 4.68 | 12.26 |
| June | 40,750 | 3,704.36 | 2,013.97 | 9.09 | 4.94 | 4.15 |
| July | 44,380 | 4,271.03 | 2,272.36 | 9.62 | 5.12 | 4.50 |
| August | 39,300 | 4,273.31 | 2,471.91 | 10.87 | 6.29 | 4.58 |
| September | 41,600 | 4,265.74 | 2,392.09 | 10.25 | 5.75 | 4.50 |
| October | 48,460 | 4,645.08 | 2,620.83 | 9.58 | 5.40 | 4.18 |
| November | 40,300 | 3,374.92 | 2,340.96 | 8.37 | 5.81 | 2.56 |
| December | 46,400 | 4,269.73 | 2,331.31 | 9.20 | 5.02 | 4.18 |
| Total or average | 493,150 | 60,738.52 | 27,832.53 | 12.32 | 5.62 | 6.70 |

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*Extraction table.*

| Month. | Depth in feet. | Dredged. | | Number prospect holes in and near dredged area. | Prospect value of ground dredged. | Prospect value of gold recovered. | Total gold recovered in cents per cubic yard. | Operating cost in cents per cubic yard. | Character of ground dredged. |
|---|---|---|---|---|---|---|---|---|---|
| | | Acres. | Cubic yards—bank measurement. | | | | | | |
| | | | | | *Cts.* | *Per cent.* | | | |
| January | 32.1 | 0.40 | 20,340 | 2 | 15.35 | 100.20 | 15.38 | 13.16 | Coarse gravel to surface; dredging across slough. |
| February | 22.0 | .90 | 32,000 | 2 | 15.35 | 69.57 | 10.65 | 6.89 | 10 feet top soil; 2 feet of gravel on bed rock; hard digging. |
| March | 28.7 | .89 | 41,160 | 2 | 37.70 | 50.00 | 18.78 | 5.88 | 10 feet soil; gravel coarse, and hard digging. |
| April | 27.0 | 1.15 | 50,760 | 3 | 37.70 | 50.00 | 18.91 | 3.65 | 12 feet top soil; 15 feet coarse gravel; 3 feet on bed rock; hard digging. |
| May | 27.0 | 1.09 | 47,700 | 3 | 16.25 | 104.24 | 16.94 | 4.68 | 12 feet top soil; gravel coarse. |
| June | 21.4 | 1.18 | 40,750 | 2 | 10.35 | 87.96 | 9.09 | 4.94 | 10 feet soil; gravel firm, and sand on north side of cut. |
| July | 22.0 | 1.25 | 44,380 | 2 | 11.45 | 84.02 | 9.62 | 5.12 | 4 feet top soil; coarse gravel on west side cut; sand streak on east side. |
| August | 26.0 | .93 | 39,300 | 2 | 11.45 | 94.93 | 10.87 | 6.29 | 6 feet top soil; sand streak on west side of cut; all fine gravel; easy digging. |
| September | 24.2 | 1.06 | 41,600 | 2 | 4.40 | 230.00 | 10.25 | 5.75 | 6 feet top soil; sand on west side of cut; all fine gravel; easy digging. |
| October | 23.8 | 1.27 | 48,460 | 3 | 5.25 | 182.43 | 9.58 | 5.40 | 6 feet top soil; sand in center of cut; remainder fine gravel; easy digging. |
| November | 31.0 | .81 | 40,300 | 3 | 17.23 | 48.58 | 8.37 | 5.81 | 7 feet top soil; east side cut in sand; remainder of cut fine, and coarse gravel. |
| December | 28.8 | .92 | 46,400 | 3 | 17.23 | 53.40 | 9.20 | 5.02 | 7 feet top soil; coarse and fine gravel full width of cut. |
| Total or average | 25.8 | 11.85 | 493,150 | 29 | 16.64 | 74.00 | 12.32 | 5.62 | |

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The figures for the several items of expense in the following tables varied from month to month throughout the year, and the averages for the entire year only are given:

*Operating and all other costs.*

| | Total for year. | Total expense per cubic yard. |
|---|---|---|
| | | *Cents.* |
| Operating expense Biggs No. 1 and superintendence | $27,832.53 | 5.62 |
| General expense, Oroville and San Francisco | 1,788.62 | .36 |
| General plant | 1,282.78 | .26 |
| Bullion expense | 251.34 | .05 |
| Taxes | 1,942.66 | .39 |
| Warehouse | 401.18 | .08 |
| Insurance | 450.00 | .09 |
| Legal | 1,070.50 | .21 |
| Total | 34,999.41 | 7.06 |

*Details of operating costs.*

| | Total for year. | Per cent of total. | Cost per cubic yard. |
|---|---|---|---|
| Labor: | | *Per cent.* | *Cents.* |
| Operative | $6,435.20 | 22.9 | 1.290 |
| Repair | 4,690.41 | 16.8 | .943 |
| Superintendence | 1,875.00 | 6.8 | .380 |
| Power: | | | |
| Dredge | 4,902.81 | 17.7 | 1.000 |
| Pumps | 68.20 | .3 | .014 |
| Hardware: | | | |
| Supplies, tools, oils, etc | 1,109.77 | 4.0 | .220 |
| Repair parts, etc | 6,768.23 | 24.4 | 1.370 |
| Freight, express, and hauling | 504.69 | 1.8 | .100 |
| Steel cables | 336.03 | 1.2 | .070 |
| Lumber | 28.06 | .1 | .006 |
| Electric supplies and work | 285.67 | 1.0 | .060 |
| Clearing ground | 794.40 | 2.9 | .160 |
| Sundry expenses | 34.06 | .1 | .007 |
| Total | 27,832.53 | 100.0 | 5.620 |

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*Repair table showing cost of labor and material on different parts of the dredge.*

| | Total for year. | Grand total. |
|---|---|---|
| Ladder: | | |
| Labor | $492.63 | |
| Material | 596.43 | $1,089.06 |
| Bucket line: | | |
| Labor | 1,328.07 | |
| Material | 3,237.35 | 4,565.42 |
| Stacker: | | |
| Labor | 894.66 | |
| Material | 1,125.04 | 2,019.70 |
| Winches: | | |
| Labor | 138.73 | |
| Material | 84.05 | 222.78 |
| Screen: | | |
| Labor | 772.42 | |
| Material | 1,498.57 | 2,220.99 |
| Pumps: | | |
| Labor | 125.50 | |
| Material | 16.80 | 142.30 |
| Power: | | |
| Labor | 311.80 | |
| Material | 541.59 | 853.39 |
| Lines: | | |
| Labor | 333.43 | |
| Material | 361.48 | 694.91 |
| Gold tables and clean-ups: | | |
| Labor | 152.03 | |
| Material | 74.71 | 226.74 |
| Contingent repairs: | | |
| Labor | 800.56 | |
| Material | 1,307.59 | 2,108.15 |

*Table of lost time.*

| | | |
|---|---|---|
| Ladder | per cent.. | 10.7 |
| Bucket line | do... | 20.5 |
| Stacker | do... | 10.7 |
| Winches | do... | 3.5 |
| Screen | do... | 9.9 |
| Pumps | do... | 2.6 |
| Power | do... | 7.9 |
| Lines | do... | 9.0 |
| Clean-up | do... | 3.5 |
| Other causes | do... | 21.7 |

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| | | |
|---|---|---|
| Total lost time | per cent.. | 32.8 |
| Dredging time | do... | 67.2 |
| Average number of cubic yards dredged per day of running time | | 2,005 |
| Actual average number of cubic yards dredged per day of twenty-four hours | | 1,347 |

*Summary of costs in cents per cubic yard, 1904.*

| | |
|---|---|
| Dredge crew and power | 2.69 |
| Repair labor | .94 |
| Repair supplies | 1.61 |
| Superintendence | .38 |
| Oroville and San Francisco general expense | .36 |
| Taxes and insurance | .48 |
| Bullion expense | .05 |
| Grand total, all costs | 6.51 |
| For three $45,000 dredges these items would have been as follows: | |
| Dredge crew and power | 2.69 |
| Repair labor | .66 |
| Repair supplies | 1.61 |
| Superintendence | .17 |
| Oroville and San Francisco general expense | .12 |
| Taxes and insurance | .27 |
| Bullion expense | .05 |
| Grand total, all costs | 5.57 |

Mr. J. P. Hutchins, of San Francisco, who has had long experience in the dredging fields of Oroville and has recently worked in the Klondike, has courteously furnished for this report an account of the present status of the industry, with suggestions regarding the forms of dredges most applicable to Alaska conditions.

## NOTES ON DREDGING.

By J. P. Hutchins.

Dredge mining of placer gold has been one of the most attractive fields for investments of capital in recent years. Prospecting methods in use to determine the values of the areas thought to be available for profitable exploitation by dredging are not complicated. Until recently well-drilling machines have been used almost exclusively in this work, and in many cases the results of such sampling have led to large investments of capital in dredging ground and dredging machinery. These drilling machines have much to recommend them. They are cheap and mobile, can be operated on floating scows to sample river, lake, or sea bottoms (see Pl. III, *A*, p. 40), or used to sample a deposit where a large volume of water near the surface would make shaft sinking very costly. Numerous holes can be drilled in a short time and at a comparatively small cost. In many cases shafts have been sunk with the drill holes for centers, and the results of the two methods of prospecting checked well.

It was first held that the results of dredging could be relied upon to equal about 50 per cent of what drill prospecting would indicate the

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values to be. The disparities were in part accounted for by attributing them to spilling, leakage, faulty discharge of buckets, incomplete excavation by apparatus, incomplete disintegration during washing in screening, and to losses in the gold-saving apparatus. It seemed, however, as if these losses should be only about 10 per cent, and the other 40 per cent was explained by the well-known general statement that "prospecting results are always high."

Up to the time that considerable areas previously prospected with numerous drill holes were dredged, the results of drill prospecting were believed to be absolutely reliable, making the allowance, however, of about 50 per cent for values to be recovered by the dredge. After these areas had been worked, however, the dredge managers found much to surprise them, for where ground had prospected well it had dredged poorly, and vice versa. It is asserted that in these instances both the drilling and dredging were so conducted that no great reliability could be attached to the results, but this explanation is far from satisfactory.

In the use of the drilling machine to sample alluvion, as in all other prospecting, unusual care must be exercised to obtain results that shall give a correct idea of the values and of the other characteristics of the ground under examination. It is unquestionably true that careless sampling has been the cause of many failures in dredging operations. The seeming simplicity of this prospecting method has, as in other apparently simple determinations, resulted in crude manipulation and misleading results. In some instances there has been a misleading affectation of accuracy in tabulating results of drill prospecting. Careless location and distribution of drill holes have given faulty results. Nevertheless, the percussion drilling machine is peerless for testing most areas that may be available for exploitation by the dredging method.

The drilling machines are used for several purposes. It is necessary to determine whether the material is too hard to make dredging profitable, and for this purpose drilling machines are not entirely satisfactory. In several areas prospected by drilling machines and thought suitable for dredges the material proved to be so hard that a machine different from the one designed was required for successful exploitation. If the prospecting had been done with more care this unfavorable condition would have been learned.

Reliable results call for the determination of the presence and distribution in the vertical section of any considerable content of tenacious clay and large bowlders, and here again the drill does not yield entirely satisfactory results. The depth of material must be ascertained and, where the bed rock is a so-called "false," the greatest care is necessary in order to determine its position. The character, hardness, and roughness of the bed rock must be learned, and the drill unfortunately

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still leaves much to be desired in connection with this phase of the investigation. In spite of these drawbacks the percussion drilling machine has no superior as a preliminary means of prospecting alluvions thought to be suitable for working by the dredging method, and this is particularly true where large volumes of water may be encountered near the surface. The sinking of shafts is to be preferred, however, where not too costly.

In several projects, where a large expenditure of money is in contemplation, so-called prospecting dredges have been used. These machines are small but complete dredges, and perform, on a small scale, the functions of the ordinary type. Their design is such that they may be readily moved, for they are equipped with lightly constructed machinery and hulls and are of light draft. If, as is frequently the case, the area to be prospected is traversed by a river or sloughs, such a light dredge is easily moved from place to place. Where there are no waterways, a still smaller dredge, to be moved on rollers or skids, can be employed.

Though the cost of installation and operation of such prospecting dredges is considerably more than that of drilling machines, the reliability of the results will often justify the additional expenditures, particularly where large areas are being prospected. By their use the values per cubic yard, character of material, presence of large bowlders and clay, and depth and character of bed rock can be accurately ascertained. There is an additional advantage of great importance in the fact that the cost of operating a large dredge can at the same time be closely determined.

The number of gold dredges in successful operation in the United States has greatly increased during the past decade, and especially in the last six years. The first successful one was operated at Bannock, in Montana, and was of the so-called "double-lift" type. The material was excavated by a chain of buckets and discharged from an elevation of about 15 feet above the deck into a trommel, which had perforations about 5 inches in diameter. Stones of larger diameter were discharged over the side of the dredge; the "fines" were elevated by a 12-inch centrifrugal dredging pump to a sluice and discharged about 100 feet astern. This type of dredge is still advocated by some managers, and unquestionably has a number of advantages over other types. It is especially good for handling material which has a clay content or which is so tenacious that gold is lost by incomplete disintegration and insufficient washing in the screens and sluices of the other types of gold dredges. The passage of the fines through the centrifugal pump of the double-lift dredge tends to disintegrate the material thoroughly and to completely liberate any particles of gold held in clay or other tenacious substances.

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The particular problem at Bannock was to evolve a dredging pump to stand the wear and tear of handling the fines of about 2,000 cubic yards every twenty-four hours. The first pump was worn out after seventy hours' use, but another of excellent construction, designed by the dredge manager, was installed and used for several years. After a seven months' run, when the fines of over 400,000 cubic yards had passed through it, it was estimated that the costs of repairs and renewals of the pump had been only about $150.

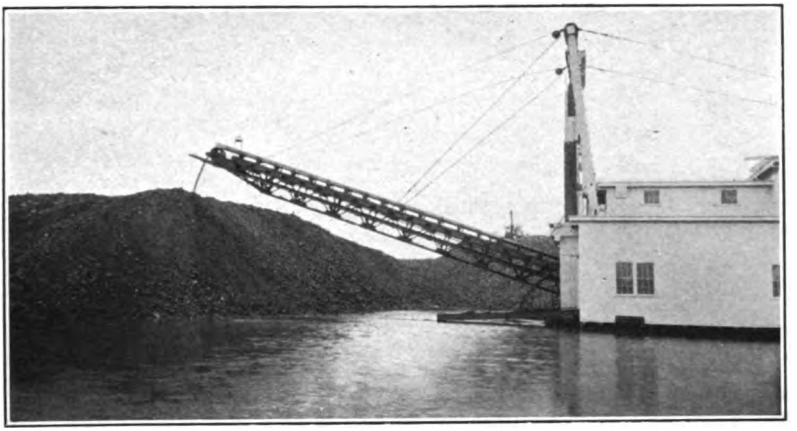
With a view of eliminating the dredging pump the so-called single-lift dredge was designed by Montana men. This type discharges the material about 28 feet above the deck into a trommel with perforations 5 inches in diameter. As in the "double-lift" dredge, the coarse material was deposited over the side, while the fines dropped into a sluice and were discharged about 100 feet astern. The greater height of discharge of buckets made a secondary lift of the fines unnecessary. This form of construction introduced a new set of problems, as the higher position of the upper tumbler necessitated longer ladders, more and heavier buckets in a longer bucket chain, larger hulls, and heavier construction throughout. Some of the first "single-lift" dredges were very unstable because of the high position of center of gravity. This type of dredge is now in more general use than the "double-lift" machines.

The dredge which had been used so successfully in New Zealand was not introduced into the United States until after the extensive operation of these two types. The first New Zealand dredge was installed in the Oroville district of California, and after a few modifications to suit local conditions was and is still operated successfully. This was followed by the building of a number of similar dredges in California, Colorado, Idaho, Oregon, Montana, and elsewhere (see Pls. XXX, *A*, and XXXI, *B*).

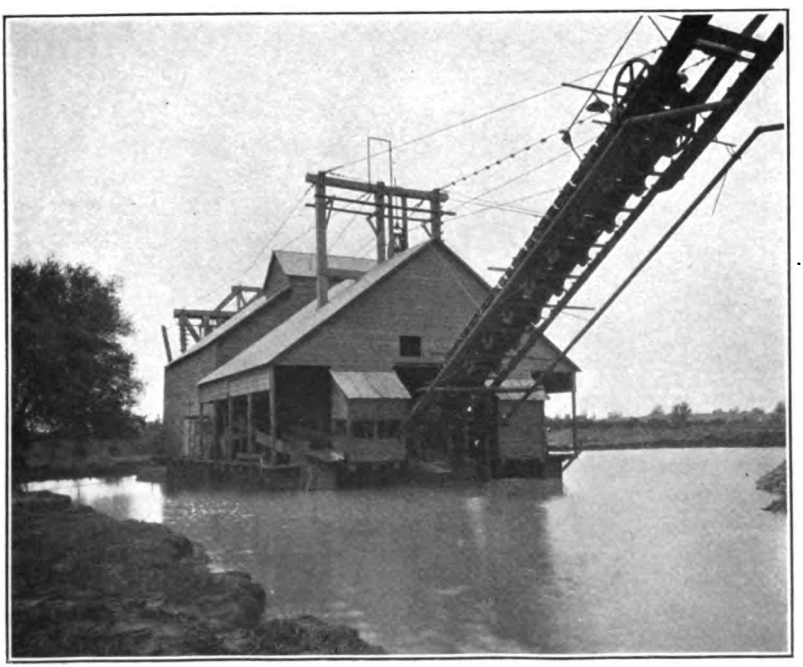
These dredges were essentially different in design and manipulation from those of the double and single lift types. While the bucket of the New Zealand type was evolved entirely for gold-dredging purposes, the bucket previously used in this country was but a slight modification of the one used for harbor and canal dredging. In both types, but more notably in the bucket evolved in harbor and canal dredging, the first made were deficient in the strength of the digging apparatus.

The New Zealand type of gold dredge discharges the material about 16 feet above the deck into a trommel, the largest perforations of which are about one-half inch in diameter. A stacker (see Pl. XXXI, *B*) made of a chain of steel buckets elevates all material not passing through perforations of trommel and discharges it astern of the dredge at a height sufficient to allow for the expansion of the tailings. The fines pass over the gold-saving devices and are dis-

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*A*. DIGGING ON SPUD.



*B*. STACKER, NEW ZEALAND TYPE OF DREDGE, CALIFORNIA NO. 1.

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charged about 10 to 15 feet astern of the dredge. On the double and single lift dredges no stackers were necessary, because the larger perforations of the trommels allowed the comparatively small percentage of stones to be discharged over the side without shoaling the water too much.

The gold-saving apparatus introduced with the New Zealand type was also essentially different. The hydraulic mining undercurrent, which is a wide sluice with steep grade, and which spreads the material over a broad surface in a shallow sheet after all stones of diameter greater than 2 inches have been removed by a grizzly, was evolved in California but had been successfully used in New Zealand in hydraulic operations. A very slightly modified form of this device was used on a number of the dredges, with the difference that cocoa matting instead of riffles charged with quicksilver was used to catch the gold (see Pl. XXIX, *A*, p. 162).

The double and single lift gold dredges depended principally, and in some cases entirely, on a comparatively narrow sluice with riffles charged with quicksilver. The material passed over the riffles in a deep sheet, a condition not conducive to a high percentage of saving, where the gold is in the form of very finely divided particles.

There is a marked difference in the manipulation of the several types of dredges. The New Zealand boat in digging is held to the face of the bank by a headline run out over the bow to an anchorage, and the buckets are lowered in a vertical plane, the material being caved by undermining at the bottom. The other types are held to the face by a pivotal stern spud (see Pl. XXXI, *A*), the buckets being side fed horizontally through an arc of 120°. The cut is begun at the surface and the digging ladder lowered about 1 foot at the completion of each arc, no attempt being made to undermine or cave the material excavated.

Several shovel dredges were built at Oroville at about the time the New Zealand type was installed. On these the hydraulic-mining undercurrent, almost the same as that of the hydraulic miner in California, and a shaking screen, similar in action to the rocker of the early-day California miner, are used. Belt stackers were also installed. The shovel dredges proved costly of operation and have, with few exceptions, been discarded.

Next in order of development came a dredge with the bucket evolved in canal and harbor dredging. The machine was very much strengthened, however, and was provided with shaking screen, belt stacker, and hydraulic-mining undercurrents, called "gold-saving tables." In this type is found a combination of the better features of the double and single lift and shovel gold dredges. Small buckets were first used, but the tendency had been toward increased capacity. This dredge was an improvement, but it had a fault common to all the



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dredges at that time and still often found—a lack of coordination of capacity in the four processes of which gold dredging consists, namely, excavating, screening, sluicing, and tailing.

The next improvement was the building of a dredge in which coordination of capacities received more attention, for in this the screens, tables, stacker, and pumps were enlarged. It was designed to work either on spud or headline, with a slightly higher discharge of material to permit of a greater elevation of coarse tailings and a stacking of them at a distance from the stern. The pivotal spud was placed inboard so as to make the digging and the tailing arcs of more equal lengths when working on a spud. The difficulties encountered when these arcs were of very unequal length were thus eliminated. The disposition of the tailings had formerly been a continual source of difficulty and expense, but this improved dredge was so designed as to allow both working on a headline and side feeding through an arc of long radius. This permitted the working of a wide cut and the disposition of tailings without covering adjacent virgin ground, for previously much untouched territory had been wasted by being covered with tailings. Impact riffles charged with mercury, i. e., those where the fines are dropped to effect amalgamation, and larger gold-saving areas were also introduced.

There have been no radical changes in the design or construction of gold-dredging machinery of late, and efforts have been directed toward the strengthening and bettering of machinery and hull and the lowering of operating expenses.

The excavating apparatus (see Pl. XXXII; Pl. XXVIII, *B*, p. 160, and Pl. XXX, *B*, p. 168) used in gold dredging has been very much improved since the first installations. Bucket forms have been modified so as to prevent losses by spilling. This is accomplished by reducing the angle made by the bucket lip with the line through the centers of the two bucket pins. With the earlier design a considerable loss by spilling, except when buckets were working at maximum depth, was noticed. In the earlier design the bucket was long, narrow, and deep, and a clean discharge was not effected, especially when working in sticky or sandy material. Recent design provides a short, wide, and shallow bucket which discharges more perfectly. The use of jets of water to wash any adhering material from both inside and outside of buckets into the hopper and save-alls is now common and accomplishes a considerable increase in the gold saving. The capacity of buckets has been largely increased, but the economical limit has not been reached nor will it be reached in the near future.

With the increase of size of buckets there has not been a proportionately greater strength, but this defect is being gradually remedied. The use of various alloys of steel in bucket parts, as well as in other

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A



B



C



D

BUCKETS.

A, California No. 3, B, E Oro, C, Indiana, D Lava Beds No. 2.

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parts of the dredging machinery where there is severe wear and tear, has been in most cases successful.

The design of the upper and lower tumblers has been modified and all parts subject to wear are now easily replaceable. In earlier installations the tumblers were of such design and construction that the wearing out of one part sometimes necessitated the loss of the whole. Some trouble has been caused by the working loose of the "wearing plates." Tumblers with more numerous faces are now also used. In early practice the square upper tumbler was supposed to be superior to the one with more faces, it being assumed that the square tumbler was more capable of firmly holding the buckets and preventing the danger of its revolving without moving the bucket chain. The hexagonal upper tumbler is now in successful operation, and it is safe to predict that heptagonal and possibly octagonal upper tumblers will be

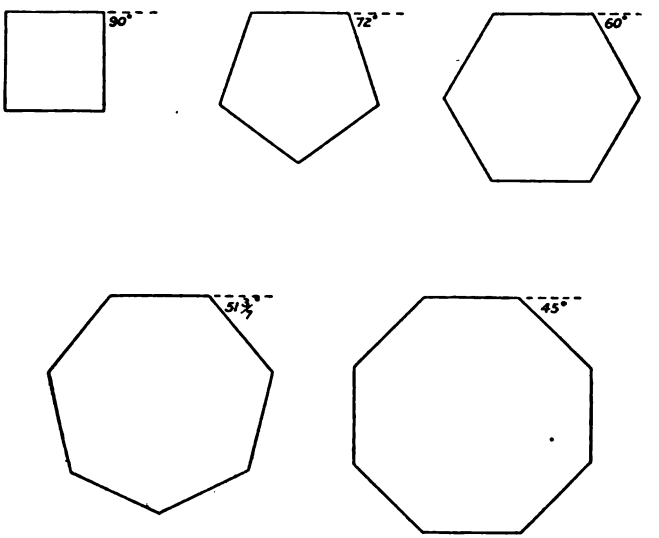



FIG. 34.—Angles for upper tumbler.

used, particularly on the smaller dredges. The objection that they will not hold is not good. Even if true, an arrangement making the relation of bucket to tumbler that of chain to sprocket would solve the difficulty. The use of the heptagonal and octagonal upper tumblers introduces a new set of problems, involving larger tumblers and shafting, different arrangement of chute to hopper, and modified forms of save-alls. These modifications are necessary because of the resulting longer period of discharge of the bucket. It is probable, however, that saving in wear of the bucket pins and bushings due to lesser deflection in turning tumblers of more numerous faces will compensate for the extra expense involved in construction.

Fig. 34, above, shows the relative size and different deflection angles made by the buckets in turning the square, pentagonal, hexagonal,

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heptagonal, and octagonal tumblers and per cent of saving of wear over the square type. The wear and tear of bucket pins and bushings is almost entirely the result of the deflection of the buckets in rounding the tumblers. A slight amount of wear is occasioned by deflections back of the lower tumbler as the buckets come in contact with the material. These last deflections, however, would be prevented by rollers such as are suggested in a paragraph on page 184 discussing the respective merits of the spud and headline.

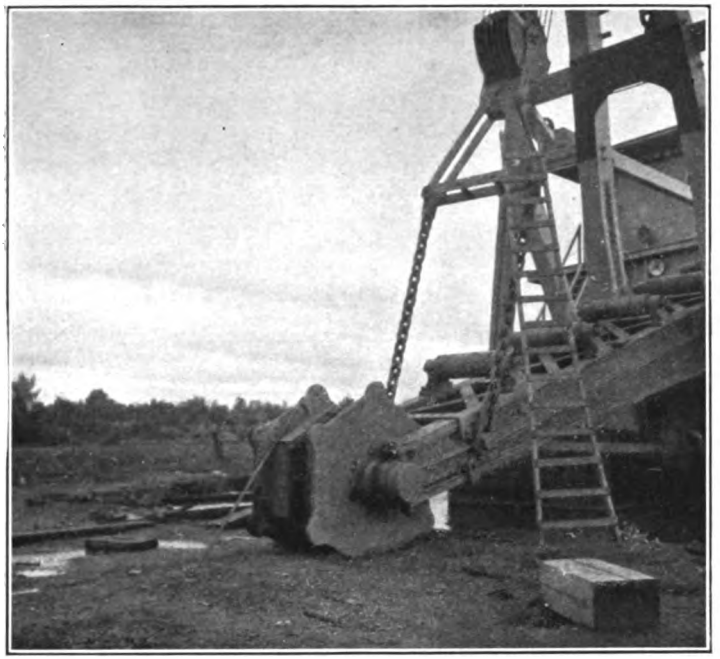
If, instead of square upper and lower tumblers, pentagonal, hexagonal, heptagonal, or octagonal tumblers are used the saving of wear of bucket pins and bushings would be approximately 40, 66, 86, and 100 per cent, respectively.

There is but one serious objection to the use of a lower tumbler of more numerous faces, i. e., greater size and weight. The great saving in wear of the bucket pins and bushings will, when fully appreciated, result in the use of both upper and lower tumblers of more numerous faces. (See Pl. XXXIII, *A*.)

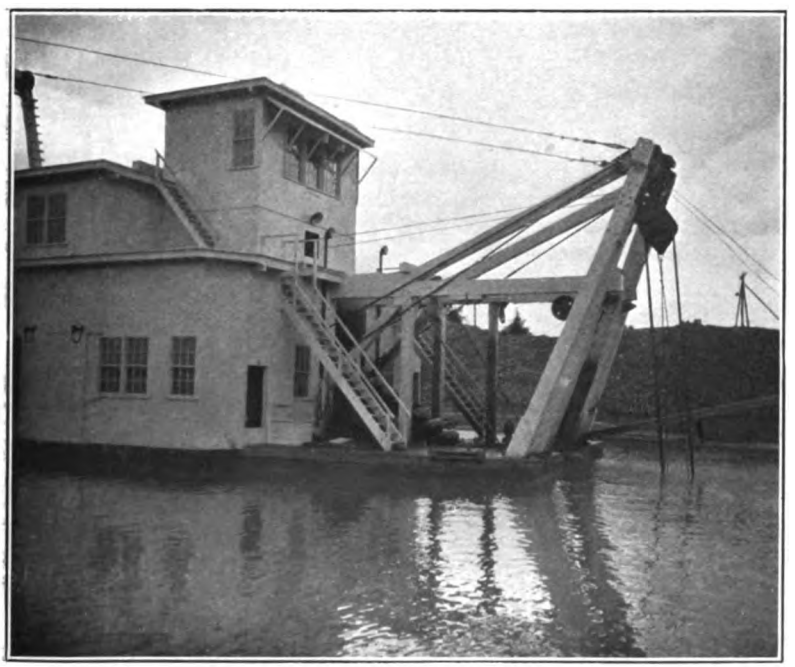
One dredge manager of much experience has suggested the use of a round lower tumbler of large diameter with buckets of short pitch, claiming that buckets seldom lie flat on tumbler faces when excavating, but frequently ride the corners between the faces. This difficulty has been observed by the writer on many occasions. A too rapid feeding of buckets resulted in considerable spilling of material upon the buckets about to round the lower tumbler. The spilled material lodged between the buckets and the tumbler faces and destroyed, temporarily, their proper relation. The use of the round lower tumbler would have the additional advantage of preventing surging (see p. 184).

Until recently it has not been generally regarded as good practice to lower the digging ladder to more than 45° from the horizontal because of supposed disadvantages in such manipulation. Recent installations provide an idler at the rear end of the well to prevent the buckets from dragging on the chutes and the save-all gratings as the ladder is lowered more than 45° from horizontal. This device permits greater working depths with a given length of ladder and makes deeper ground available for the dredge. Pl. XXXIII, *B*, illustrates diggings at a low angle. There is a marked diversity of opinion among managers as to the relative merits of the trommel and shaking screen. The trommel advocates have claimed better mechanism, cheaper maintenance, more efficient screening when material is at all tenacious, and economy in power. The advocates of the shaking screen have claimed larger capacity with given weight, higher percentage of gold saving because of better opportunities for amalgamation by impact, and easier and better distribution of material over the gold-saving surfaces.

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*A*. LOWER TUMBLER, CALIFORNIA NO. 3.



*B*. DIGGING LADDER AT LOW ANGLE, OROVILLE, CAL.

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The trommel (see Pl. XXIX, *A*, p. 162) is a better mechanism, requires less power for operation, and gives much less trouble in maintenance than the shaking screen and does cleaner screening, particularly when the material is at all indurated or tenacious. Trommels have almost without exception been too small, and all late installations are larger. Amalgamation by impact is now accomplished by a special arrangement of the gold-saving apparatus, and distribution of water is no longer a difficult problem on dredges where trommels are used. One of the most recent installations by a company which has extensively employed both devices includes a trommel. At present in most cases the trommel is in high favor among Oroville operators.

Where there is an overburden of any considerable depth the use of a device to blank the trommel or screen will be a distinct improvement. By its use all barren material can be stacked well back of dredge and usually at a more rapid rate than if handled in the ordinary way. Overburdens, which it is always necessary to dispose of as quickly and cheaply as possible, usually consist of a fine loam or sand which can be run but slowly over the gold-saving devices because of clogging when handled rapidly. A blanking device was used for a time at Oroville and worked well, but, because of bad design, required too much time in blanking and unblanking the screen. Its use, however, allowed the beginning of dredging operations, on interior ground, without the use of a sand pump and the immediate excavation to a depth of 30 feet, with a consequent minimum wasting of dredging ground. The use of such a device involves a large discharge of material from screen or trommel to the stacker where a troughed belt is used. The incline of the stacker must not be so steep as to permit the material, which is often a thin mud, to run back to the end.

The use of a device to blank the hopper which shunts the material into the well has been tried, but has not been entirely successful. In this case also, bad design rather than bad principle was responsible for failure. The disposition of an overburden by this method is to be heartily recommended, especially where dredges work on headlines, as they are thus enabled to distribute the barren material across most of the width of the cut.

The gold-saving apparatus, after many experimental modifications, including the introduction of various magnetic and intricate devices, has returned to the hydraulic-undercurrent type with the mercury riffle. For saving clean gold the mercury riffle is probably best. When, however, for any reason there is imperfect amalgamation, the use of some form of woven material to enmesh particles of rusty gold is good practice.

The increase of the area of gold-saving surface has met with good results. Steeper grades are now used for gold-saving tables than for-

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merly, and arrangements are such as to allow a better distribution of sluicing water to various parts of the gold-saving areas. Gold-saving surfaces are now generally arranged in a number of drops, and the material impinges upon riffles charged with mercury and is amalgamated by impact.

Much thought has been recently given to the perfecting of save-alls, and a surprisingly large amount of gold, sometimes 10 per cent of all saved, is recovered in this way. The design of save-alls in the earlier practice was somewhat neglected, but in the general refinement of working methods a considerable improvement is being effected. A device for keeping under lock and key parts of the gold-saving apparatus where the largest proportion of gold is caught has been introduced.

The troughed belt stacker seems to be generally regarded as superior to the bucket stacker (see Pl. XXXIV, *B*) because of greater economy of operation and less weight for a given length. Stacker belts are a source of large expenditure because of the rapid wear due to the insufficient thickness and inferior quality of the material which covers the woven part of belt and which gives the belt its wearing qualities.

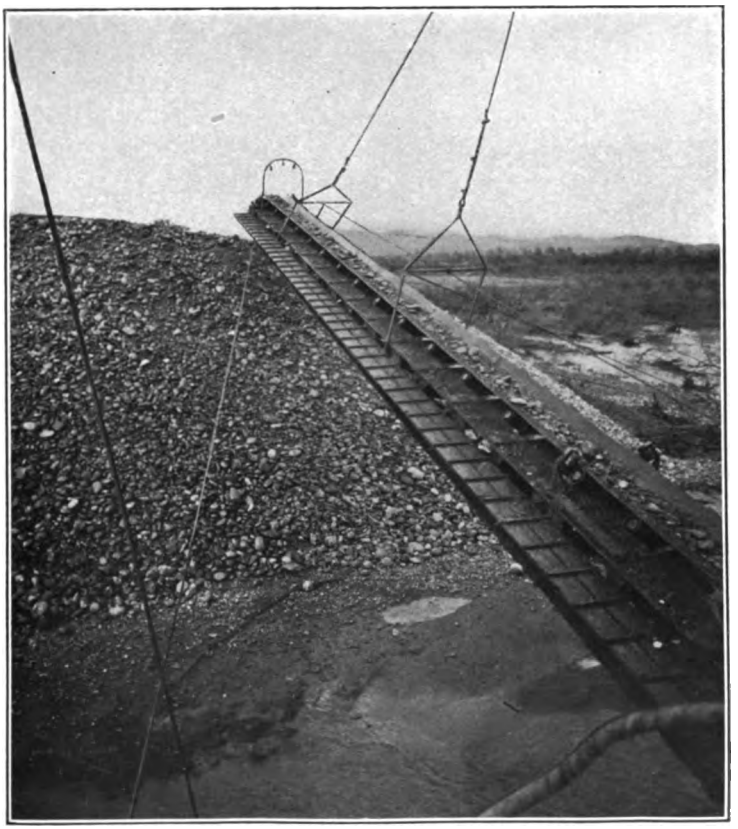
Nearly all the recently installed stackers have the driving pulley on the outboard end, and electric dredges have the driving motor, as well, on the outboard end. (See Pl. XXXIV, *A*.) This arrangement has eliminated a number of troublesome features. If the stacker is driven by rope or sprocket chain from a motor on the dredge, there is much trouble due to wear, slipping, and stretching of ropes and of sprocket chains. If the driving pulley is at the inboard end of the stacker, the load is pushed uphill on the slack side of the belt, and there is much trouble from slipping and stalling. A belt stacker driven by the inboard pulley requires more power than one operated by the outboard pulley.

At one time it was generally thought that when coarse gold occurred in the material dredged, either the double or single lift type of dredge must be used. Stacker dredges are now used and have at the lower end of the trommel perforations large enough to pass material up to 1½ inches in diameter. This material and water run through a sluice where gold is saved and are then deposited in the stacker buckets. With such a device under ordinary conditions a troughed belt stacker could not be used, as it could not handle the water. Any device that would remove water and deposit pebbles on the belt without too many complications would allow the use of the belt stacker. (See Pl. XXXV, *A*, p. 184.) It would not be expedient to use a double or single lift dredge where ground is deep. To effect disposition of tailings while operating the double and single lift dredges it is necessary to keep the pond nearly full and to use very long digging ladders.

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*A.* UNCOMPLETED BELT STACKER, OROVILLE, CAL.



*B* TROUGHED BELT STACKER, OROVILLE, CAL.

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Stackers and tail sluices are of greater length than formerly. In early installations, without a single exception, stackers and tail sluices were too short, and difficulties due to improper disposition of tailings were of constant occurrence. Considerable areas of rich dredging ground, particularly when deep, have not been thoroughly worked, and much virgin ground has been covered by tailings to such a degree as to make it unworkable. The short stacker does not allow the coarse tailings to be discharged at a sufficient distance from the stern and at the proper height. There is consequently lack of room for fine tail-

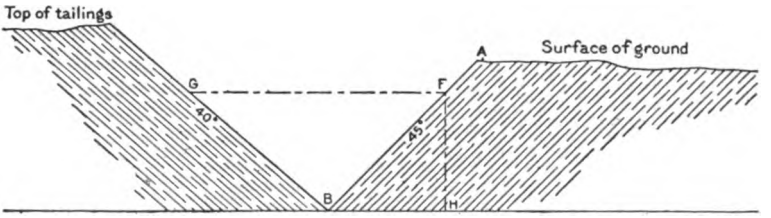



FIG. 35.—Tailings well stacked.

ings. In consequence the sand pump was brought into use, and the fines were discharged in such a way that much adjacent ground was covered by them. Valuable dredging ground, even now, is being wasted in this way, as also by faulty manipulation of the dredge. The tailings have not been stacked with enough care to keep them well away from the sides of the cut when there is virgin ground on one or both sides.

Fig. 35 shows the cross section of tailings so piled as to waste no ground. It is assumed that the side slope of the cut is 45°, but this is

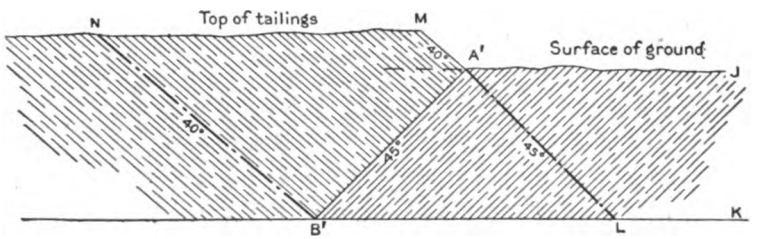



FIG. 36.—Tailings poorly stacked.

the case only when ground is very free. "B" in the sketch is the boundary of the cut on bed rock. "A" is the boundary of slope to 45°. F G is equal to 2 F H. Tailings, as a general rule, should be so stacked that the distance from the tailings to the side of the cut at the surface of the water is about twice as great as the depth to which the dredge is digging.

A cross section showing the result of stacking tailings badly is indicated in fig. 36. This cut has been filled with tailings to point A', the boundary of the cut at the surface. In excavating the cut, of

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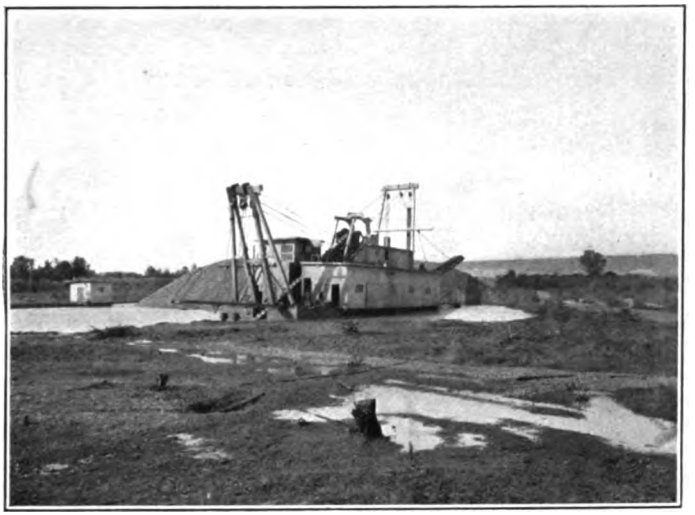
which A′, L, K, J is a part of cross section, it would not be possible to dredge beyond the point L in the direction of B′ without having to dig tailings in section B′, A′, M, N. If the material in the triangular section is assumed to be loose and to stand at an angle of 45°, angle A′, L, B′, the undredged ground in section B′, L, A′ would be lost.

At first the relative merits in the use of a pivotal spud or a headline were considered almost wholly from the standpoint of actual excavation, and the difficulties of disposing of the tailings did not receive nearly the attention their importance demanded. In the opinion of the writer the pivotal spud should be used only by dredges of the double and single lift type whose sluices are sustained by auxiliary scows. Several dredges of these types in Montana, having broken a number of pivotal spuds while dredging a tenacious material, have substituted a system of rope anchorages which does not recommend itself to the writer, as it appears better to make use of stronger spuds. The rigging consists of four wire ropes leading from a high frame at the stern to anchors ashore. The pivotal spud appears to be more effective in holding the dredge when excavating indurated material and prevents its surging and ramming the bank. Attempt has been made to prevent this movement in headline dredges by placing the buckets closer together and thus bringing about greater continuity of contact between the buckets and the dredging surface. This, however, has not been entirely successful. It is possible that the introduction of a number of rollers on the lower side of the bucket ladder and behind the lower tumbler would result in holding several buckets firmly against the material being excavated and prevent surging, as it is probable that this movement, in digging hard material, is caused by the alternate taking hold and letting go of the buckets, as only one bucket at a time is held firmly by the lower tumbler. The buckets behind the lower tumbler dig by their weight only, which is insufficient to force them into hard material. The use of some such device as above suggested, if successful, would probably make it possible for a headline dredge to excavate indurated material with the very important advantages of mobility and the better distribution of tailings.

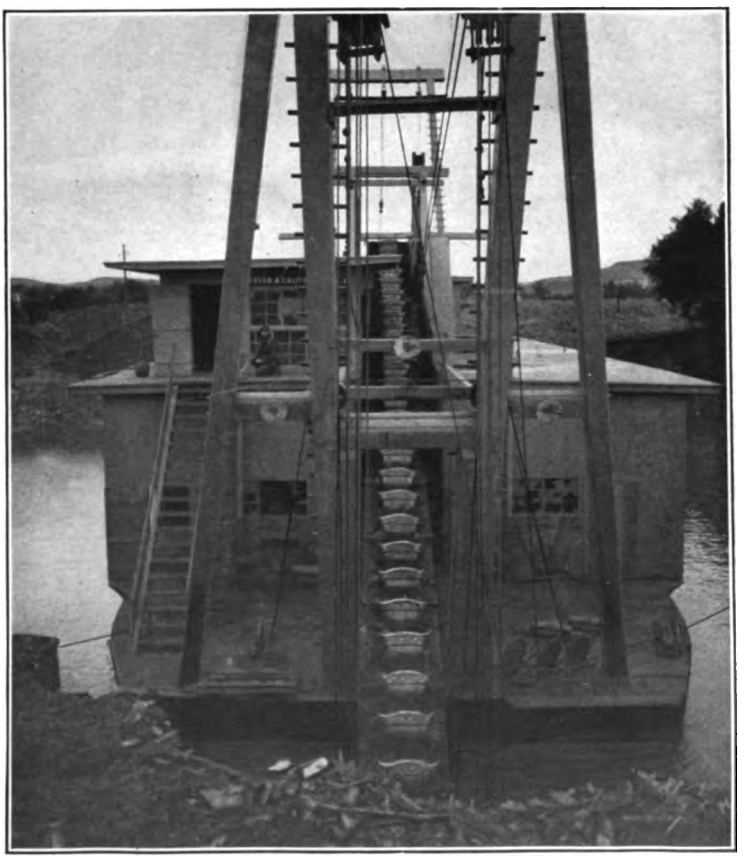
The use of lower tumblers of more numerous faces causes more buckets to dig at a time and results in less surging. It is possible that the use of a round tumbler of large diameter might entirely eliminate the surging, for there would then be no raising and lowering of the buckets as there is during the revolution of the tumbler of few faces.

The use of the pivotal spud introduces a number of problems in the disposition of tailings. The spud should be so located as to make the radius of the arc described by the buckets in digging as long as possible, thus permitting the excavation of a wide cut—an obvious advantage. This demands the placing of the spud at or near the stern. The

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*A*. PRACTICE IN POND DREDGING, OROVILLE, CAL.



*B*. PILOT HOUSE, UPPER DECK, STARBOARD SIDE.

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older boats were provided with short stackers and tail sluices, which resulted in the narrow distribution of all the tailings, but more particularly the fines. Under these conditions the stern of the dredge was frequently aground, unless kept clear by the use of a sand pump. This difficulty has been remedied to a certain degree by the lengthening of stackers and tail sluices, but will always be much more serious for the pivotal-spud dredge than for the headline dredge. The headline dredge can use the maximum amount of tailing area. For example, in unusual cases, as in dredging a pay streak of defined boundaries, tailings can be deposited on barren ground outside of the cut. To accomplish the same result with a pivotal-spud dredge numerous changes of position would have to be made, an expedient likely to result in much loss of time and some loss of ground because of the difficulty of relocating the pivotal points. The wasting of unworked ground by the faulty discharge of tailings is well illustrated by fig. 37. In this the distance from the pivotal point to the lower end of bucket ladder excavating at the maximum depth, called the digging length, is 90 feet. Here P $x$ and P $y$ represent the distances from the pivotal point to the point of discharge of the stacking ladder and are called "tailing lengths." Here the discharge is at points marked $z$ and $z'$, which are, respectively, only 18 feet and 5 feet from boundaries of cut, whereas they should be not less than 40 feet away, if the dredge be digging in ground 20 feet deep. It also shows that in some methods of manipulation too long a stacker is detrimental. This illustration is taken from two dredges now in operation.

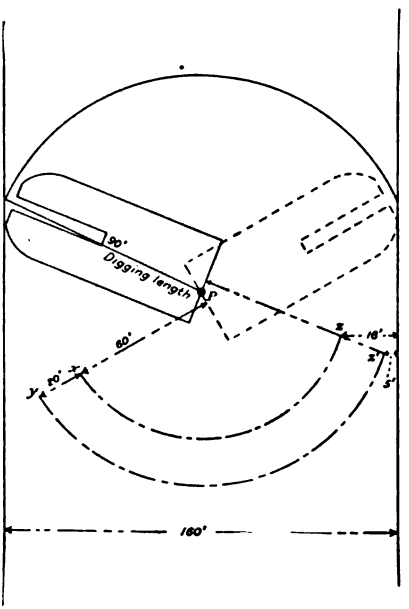



FIG. 37.—Spud digging with tailings piled too near unworked ground.

In fig. 38 a method in general use is shown to prevent the covering with tailings of unexcavated material adjacent to cut. To bring this about it is necessary to move the dredge from P to P′ as often as the distances from C and C′ to $x$, while moving ahead in excavating arc A, B, C, and in the advancing of tailings in arc $x$, $y$, $z$, become so short as to make it difficult, as $x'$ approaches P, and $x$ approaches P′, to move to and dig in the other half of the cut. The changing of the dredge from one half to the other half of the cut is generally made every few days and consumes considerable time. There is, moreover,

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the constant danger of the dredge not being located with the pivotal point in the right place and thus, when changing from one half cut to the other, there is a consequent loss of ground. In this figure it is assumed that the dredge is digging 20 feet below the surface of a pond on a bank 30 feet deep.

In fig. 39 the result of keeping the lines of advance of the pivotal points too close together is shown. The dumping of tailings at $x'$ and $x$ would result in grounding the dredge. In this case the distances from $z$ and $z'$ to sides of cut are unnecessarily great. It is evident that if the lines of advance of the pivotal points are kept too far apart ground adjacent to the cut will be wasted. In general, it may be said that where the material to be dredged is free, the headline method is

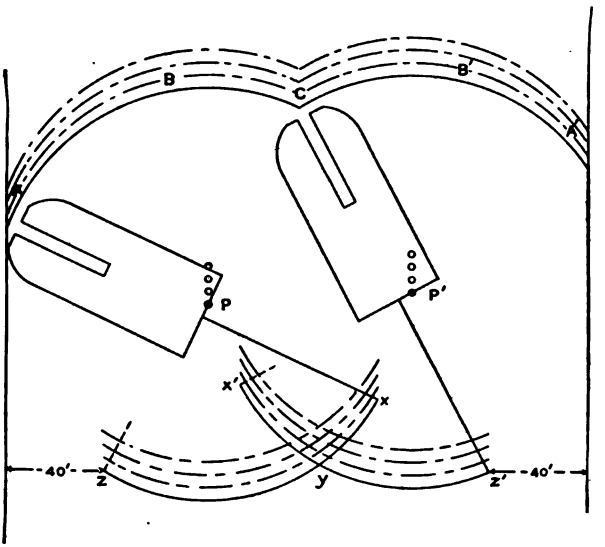



FIG. 38.—Correct spud digging from two pivotal spuds.

superior, and also, if by the introduction of some device, surging can be prevented, the headline method would be superior in dredging indurated material, for there the problem of the disposition of the tailings is much simpler. This permits of the use of shorter stacker and tail sluices and, therefore, smaller hulls and lighter construction.

There is a marked tendency now toward stronger hull construction, and longitudinal bulkheads or fore and aft keelsons are often introduced. Traverse water-tight bulkheads at the bows would be advantageous in dredges working in torrential rivers where there is danger of collision with floating trees; or, in rivers like those in Alaska, where ice may be encountered.

In some instances machinery too heavy for the size of the hull has been installed, and, as a result, there has been a lack of stability of the

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dredge, with consequent disturbance of the grades of the gold-saving devices. Hulls are now generally made with overhanging houses, which give more deck room and permit of the location on board of a small though very convenient shop. The crowning of decks has resulted in cleaner and drier dredges.

Stronger gauntrees have been introduced in the late installations. The bow gauntree, at first considered merely as a support for the outboard end of the digging ladder, is made much heavier, as it is now designed also to tie together the bow pontoons.

The main gauntree, on which are sustained the upper tumbler and its driving gear and the inboard end of the digging ladder, is made much stronger than formerly, particularly when the upper tumbler has a gear drive and a good alignment becomes therefore essential. In

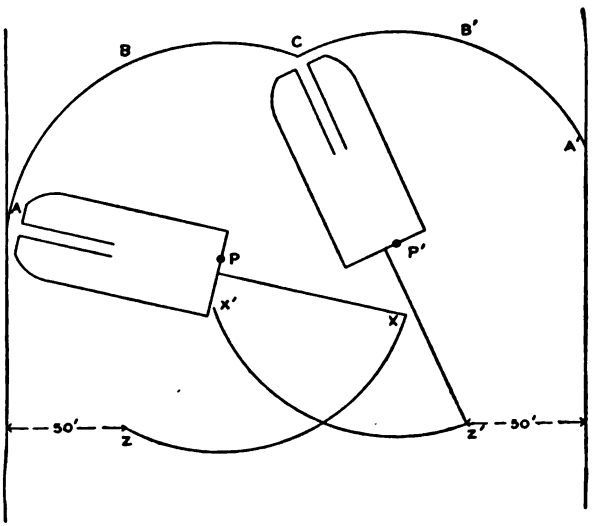



FIG. 39.—Sketch showing danger of grounding boat in tailings when pivotal points are too close together.

dredges recently constructed the main gauntree has been made the vertical post in longitudinal and transverse trusses which tend to prevent the distortion of the hull, due to the great weights of the digging and tailing machinery, which are sustained respectively at extreme bow and extreme stern. Stern gauntrees have not been much modified, but have been strengthened and made somewhat higher, so as to sustain longer stackers.

The introduction of some form of derrick or crane, at the bow, to move stumps and other obstructions and to hoist machinery, is now common. The use of traveling cranes over driving and other machinery is not so general as it should be, for such devices save time and labor when, as is frequently the case, renewals or repairs are necessary. The machinery is now generally housed.

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The location of operating levers, controllers, and switches is still a mooted question. Some operators prefer them on the lower deck close to the driving machinery; others in the pilot house, which is located near the forward end of the upper deck. In some installations they are placed in a pilot house just aft of the upper tumbler. With the first arrangement the winch man is among the driving machinery and can watch it, but unless he leaves his station he sees little of anything else and gets a poor view of the whole length of buckets. With the second arrangement the winch man can see the buckets better, all bowlines, but little else. With the third arrangement the winch man sees the buckets, the lines at bow and stern, the hopper, the screen, and enough of the gold-saving apparatus to know whether the riffles are clear, and with the aid of mirrors can also see the stacker and tail sluices. The objection to this arrangement and, in a measure, also to the second is that the winch man is isolated and therefore inaccessible (see Pl. XXXV, *B*, p. 184). The type of dredge and height of upper tumbler should determine the position of the operating levers, controllers, and the switches, but in general it would appear that the advantage would lie with a location behind the upper tumbler.

Loss of time has always been a serious factor in the use of gold dredges. The first installed in the United States operated less than 50 per cent of the time. This was due to several causes, but principally to the time consumed in making repairs and renewals and the difficulties brought about by the faulty arrangements for disposition of tailings. Minor causes, such as lack of cranes and derricks, can be overlooked, being unimportant by comparison. The writer, however, has seen the removal of troublesome stumps consume hours when, almost without exaggeration, it may be said that minutes should have sufficed for this purpose. It is noteworthy that many operations are hampered by lack of a sufficient number of lights for doing night work on or near the dredges.

All dredges should be equipped with devices for hoisting and moving the driving, screening, and pumping machinery, but these are now often lacking. The belting, both for stacking and driving, has caused much loss of time—a result due both to the poor quality of belts and to the attempt to make belts do work for which they were not intended. Friction clutches, hoppers, and screens of bad design and inaccessibility of parts of equipment have also brought about a serious loss of time. This is specially true of renewals of such parts as baffle plates of hoppers and perforated sheets of screens.

Cleaning up also consumes much time, and any arrangement that will permit continuous running during clean-ups of riffles charged with quicksilver will be of great value. Of late some managers have employed rather large crews to minimize lost time, though many dredges are still operated with but two men per shift.

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The now general use of variable-speed motors on electric dredges has had good results. Constant-speed motors on headline dredges working in indurated material had brought the headline method of dredging into bad favor, whereas variable-speed motors permit a chain speed suitable for indurated material, with less surging and breakages. Under these conditions about the same amount of material is excavated, as a slow chain speed with low theoretical capacity has often in tenacious gravel a greater actual capacity than a high chain speed with high theoretical capacity. This is due to the incomplete filling of the buckets when running at too great a chain speed.

In Alaska, where much frozen ground is encountered, the conditions are not favorable for the successful operation of gold dredges, especially as the long winter reduces the number of working days to about one hundred and thirty a year. Nearly all the deposits of auriferous alluvions are frozen, though some areas, notably in the beds of rivers, are unfrozen. Such unfrozen zones are easily dredged and large volumes can be cheaply handled. The depths to bed rock are moderate, but the bed rock is generally unfavorable for easy excavation, and the ground is characterized by a great concentration of values near and in it. Lateral concentration also is great and the pay streaks are often narrow. High costs of installation and operation are other drawbacks in regions far from the coast, to which freight charges are high. Considerable areas of so-called "worked out" ground in this northern field, particularly in the Klondike district of the Yukon Territory, would furnish excellent dredging ground if the material were not frozen. Steam thawing now costs about 40 cents a cubic yard, but a cheaper method of thawing would make much ground available for highly profitable dredging. It is probable that if wide cuts were made the banks might thaw as rapidly under exposure to the sun as they could be removed by the dredge. Another factor which may be of importance is that ground which has once been worked does not freeze to any great depth. It is evident that the chief problem of gold dredging in this northern province is in the thawing of the material, for many of the other conditions are favorable for profitable exploitation by this means.

Had gold dredges been used in the North when the first mining was done on the richer creeks much more gold would have been recovered and the cost would have been less, for the earlier methods were exceedingly wasteful and costly. The overburden of muck could have been easily sluiced off and the thawing of the underlying gravels would have been easy when aided by exposure to sun and air.

In this northern region, because of the small vertical section and absence of much fine sand in the gravels, dredges with short digging ladders and stackers can be used. This equipment demands only small, light hulls and machinery. Large volumes of thawed material can be

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handled, but screening devices for saving coarse gold are essential. Bucket rather than belt stackers are preferable, for ice on the faces of the driving pulleys would cause slipping. The climatic conditions demand that the dredges should be completely housed, and that those driven by electricity should be equipped with electric heaters to supply hot water to the gold-saving appliances and thus permit continuing operations after cold weather has put a stop to hydraulicking and open-cut mining.

Open connected buckets will do better work in the heavy bed rock usually encountered in Alaska, and teeth on bucket lips will probably be effective. The use of several powerful digging teeth in the bucket chain, instead of toothed buckets, to excavate heavy bed rock, was suggested by a manager of wide experience, and has worked well in several instances. A larger factor of safety should be allowed in designing dredging machinery intended for Alaska, and strenuous efforts made to minimize lost time in every feature of the construction, so that full advantage may be taken of the short available season.

## SLUICES AND GOLD-SAVING APPLIANCES, EXCLUDING HYDRAULIC OPERATIONS.

Creek miners in the Klondike and Alaska placer fields have met, with extraordinary vigor and a considerable amount of success, the peculiarly difficult conditions attendant on mining operations in the Northwest. Inventive genius has been called largely into play, since, except in parts of Seward Peninsula, hydraulic mining in working the creek deposits is not practiced. It is evident, however, to one who visits the Klondike district, that the methods there in vogue for working the rich creek deposits have been developed with special attention to the economical mining and conveying of the material to the sluice, while the washing of the gravel in the sluice is not, as a rule, conducted with a view to the saving of the greatest economic amount of the gold. Whereas in the hydraulic-sluicing methods the benefit of long experience has resulted in generally commendable practice, the smaller hand and mechanical creek operations frequently exhibit gross carelessness in the matter of gold-saving appliances.

The method of shoveling by hand into a string of sluice boxes is naturally the one first tried by the miner in a remote district, working in shallow ground, after he has passed the panning and rocking stage. In these operations the cost, even under present northern conditions, varies from $1.25 to $2.50 per cubic yard (averaging $1.63), the capacity per man per shift averaging 5½ cubic yards. The most primitive appliances are the most economical. From three to six boxes, 12 or 14 inches in width by 12 inches deep by 12 feet long, on a grade of 6 or 7 inches to the box length, fitted with 6-foot 3-inch pole riffles made of saplings, form the customary rig in the interior where timber

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is at hand. From 30 to 60 miner's inches[a] of water are used. Operations of this kind, where from three to twenty men shovel in, are to be found on all the gold-bearing creeks exploited in Alaska, though in the Klondike they have been largely supplemented by methods employing less hand labor. As none but rich gravel can be so worked, exigency permits a loss of fine gold. It is rare that placer miners will admit that they are losing gold, but it is safe to estimate that in the interior, where two to five boxes are in use for saving, and where drop-offs are not used, or are only such as are caused by the telescope connection of the boxes, from 10 to 20 per cent of the gold lifted into the boxes is allowed to return to the creek bed.

It would seem that heavy losses must occur in connection with the sluicing of the winter dumps taken out in drifting operations. The strings of sluice boxes are erected at as small an elevation as possible, in order that the greater proportion of the material will not have to be rehandled when the spring sluicing is done. Pl. XXXVI, *A*, shows one method of dumping, in the winter, over previously erected sluices. Boards are laid over the sluices, and when sluicing is resumed the water is turned through the sluice, and, beginning at the lower end, the boards are successively removed. As much of the gravel as possible is caved in, sometimes with the assistance of a nozzle, and the remainder is shoveled, wheeled to, and dumped into the sluice. Small bunkers or hoppers are sometimes built over the sluices, but no hoppers of large capacity, like those in use in Plumas County, Cal., were seen in the north. On Anvil Creek, in Seward Peninsula, a large winter dump was handled in this way, with the exception that those portions which could not be caved to the sluice were conveyed to it and dumped in by means of horse scrapers. Though loss of gold may be permissible in primitive operations of small capacity, it should become proportionally less when larger mechanical installations are made and the capacity of the plant is increased.

One of the early difficulties which the miner in the interior encountered was the presence of sticky clay and mud in the rich pay dirt. The difficulty was partly overcome by the introduction of the mud box, or puddling box, which was set in the middle or at the upper end of the string. Into this the men shoveled, or a bucket or car dumped. Pl. XXXVII, *A* (p. 194), shows the form of the mud box used in the Klondike, and fig. 40 shows its position in the line of boxes. Its grade is generally made steeper than that of the rest of the string; 12 inches is common. The services of an extra man as stirrer, who also forks out the large stones, are required.

Where men shovel into boxes the mud box is used merely as a wide part of the sluice. In larger plants, where buckets, cars, or

[a] The term miner's inch used in this paper signifies an amount of water equivalent to 1½ cubic feet per minute.

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derrick skips dump into the mud box, a platform, inclined at an angle of about 50°, 9 feet square, and built up of timber floored with rough scantling, is erected on the side of the box for the gravel to fall on.

The capacity of the sluice is cut down rather than increased by the use of the mud box, and the expense is increased by the cost of the man. A greater saving of gold is made, but at best the operation is expensive and of small and variable efficiency. In some shoveling-in operations the use of the mud box is advisable, but where mechanical self-dumping buckets are used, it is possible that some other form of agitator might be advantageously employed.

The developments of the open-cut and drifting methods of gravel mining have necessitated an enlarging of the sluicing capacity. With

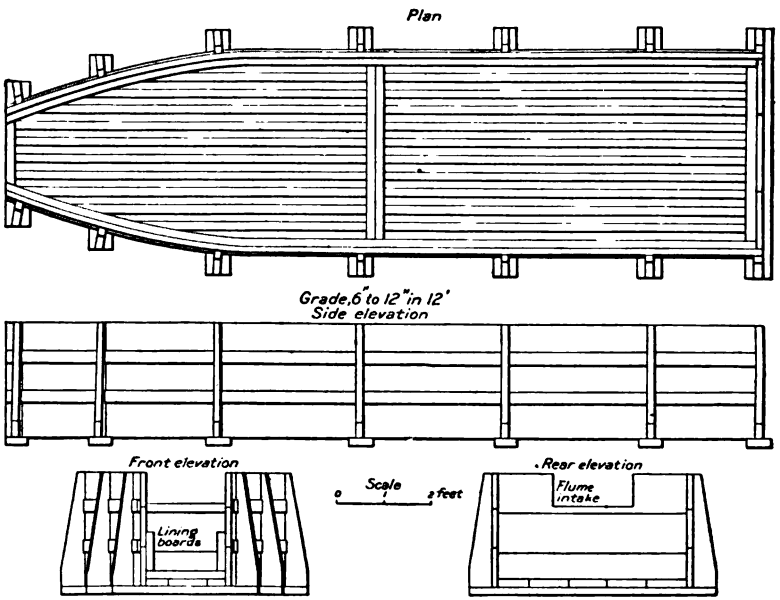
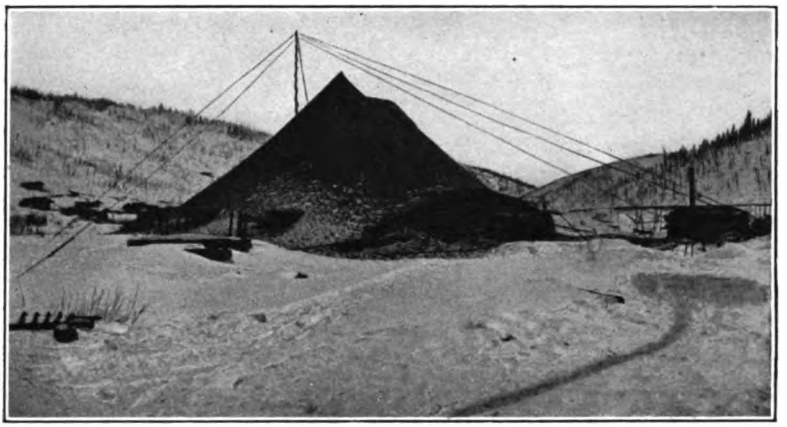



FIG. 40.—Mud box.

the enlarging of the capacity, however, there has not been a proportionate improvement in the construction of the gold-saving appliances. In other words, instead of drawing on the experience of the hydraulic miner and the dredge miner for the adoption of gold-saving methods, the creek miners of the Klondike have continued the method of the long, narrow sluice used for shoveling-in operations, amplifying its error and suffering the inevitable losses of fine gold which its use entails.

The average capacity of a small placer operation where hand labor is employed is 40 cubic yards a day of ten hours. Grant that the narrow sluice of 36 feet in length with pole riffles is most economical for the needs of such a mine. Now take an average summer drifting

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*A*. WINTER DUMPS, SHOWING PREVIOUSLY ERECTED SLUICE BOXES, KLONDIKE.



*B*. MUD BOX, USED IN STRING OF BOXES.

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plant, where the gravel is dumped into the mud box by means of the cable tram and self-dumping carrier, like that illustrated in Pl. XXXVII, *A*. The capacity is 175 cubic yards in twenty-four hours, and the cost is approximately $1.50 per yard. After it is hoisted from the shaft the material is elevated to a height of 25 feet above the surface of the ground. Water is pumped to this height for sluicing. The sluice consists of a mud box 16 feet long and 30 inches wide, on a 12-inch grade, tapering to the 14-inch sluice boxes which follow. There are eight of these, set on grade of 10 inches to 12 feet, furnished with pole riffles, which last three weeks only and cost $3 per box length to renew. The man forking in the mud box costs $6.50 a day of ten hours. At this plant the gold is in part very finely divided, and it is impossible to believe that the sluice in use is operating with economy.

Proof of the losses now going on in the Klondike was seen on a neighboring creek. At a plant somewhat larger than the one above described, where 240 cubic yards a day were handled at a cost of $1 a cubic yard, a small undercurrent had been installed, at the end of ten 16-inch boxes, 12-inch grade, pole riffles. The undercurrent was fed through a small iron grizzly, and consisted merely of one 16-inch sluice box, 12 feet in length, with a riffle of cocoa matting and expanded metal. It cost $20 to construct this device, which was saving an average of 5 per cent of the product each day. A sample of the gold was taken, and although some of it is too fine for handling, such particles as could be weighed and counted gave a result of 280 colors to the cent, the gold being worth $15.60 per ounce. Gold of finely divided but never flaky character was seen in all the large producing creeks of the Klondike, and at the new Fairbanks district of Alaska.

The plants above referred to represent the average capacity of the creek mines of the interior of Alaska, where the hoisting of material, and frequently the pumping of sluice water are necessary. It costs from $3,000 to $5,000 to rig up such plants, which are used for three seasons or longer. To install a washing plant in such a case as the above would add little to the first cost, and the additional expense would probably be justified by the results.

Before entering on suggestions as to the use of washing plants, I wish to emphasize the fact that the methods of sluicing in use in Alaska, especially in the Birch Creek, Fortymile, and Fairbanks districts, and to a certain extent in Seward Peninsula, have been, and will continue to be, influenced by the Klondike developments. Though many of the methods developed in the Klondike are excellent and are worthy of imitation in any country where conditions are similar, at the same time the Alaskan miners should note the wrong principle of the primitive sluice box which has been continued there. The entire



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absence of screening or use of grizzlies, other than the rough, expensive hand method employed, renders valueless much ground which could be worked. A plant costing $5,000, designed to thaw, excavate, hoist, convey, and wash 150 cubic yards a day at a cost of $1 a yard, could, by an addition of from $500 to $2,000 to the first cost of the plant and an addition of 10 cents per yard to the cost of washing, recover at least 10 per cent more value in gold from a cubic yard of material.

It may be said that the fine gold found in the Klondike does not occur in the Alaska creeks. This is disproved by experiments made on small parcels taken from pannings on the various creeks. Fine gold from Fairbanks Creek, in the Tanana district, runs 500 colors to the cent, the gold being worth $17.70 per ounce. A small proportion of gold from Ophir Creek, in Seward Peninsula, was found to run

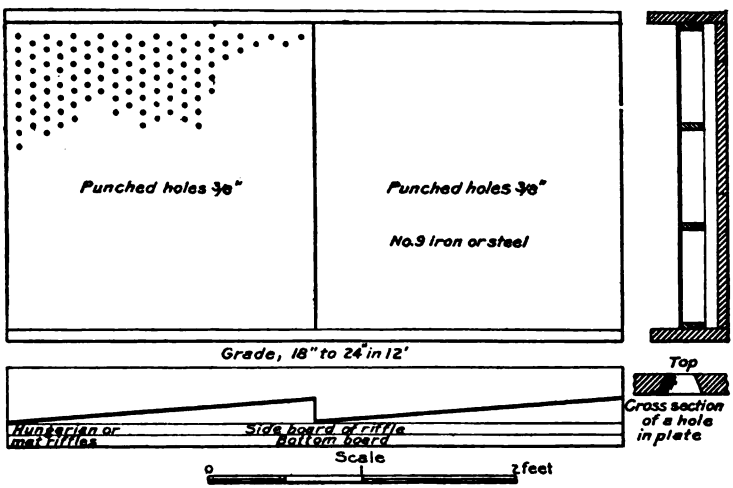


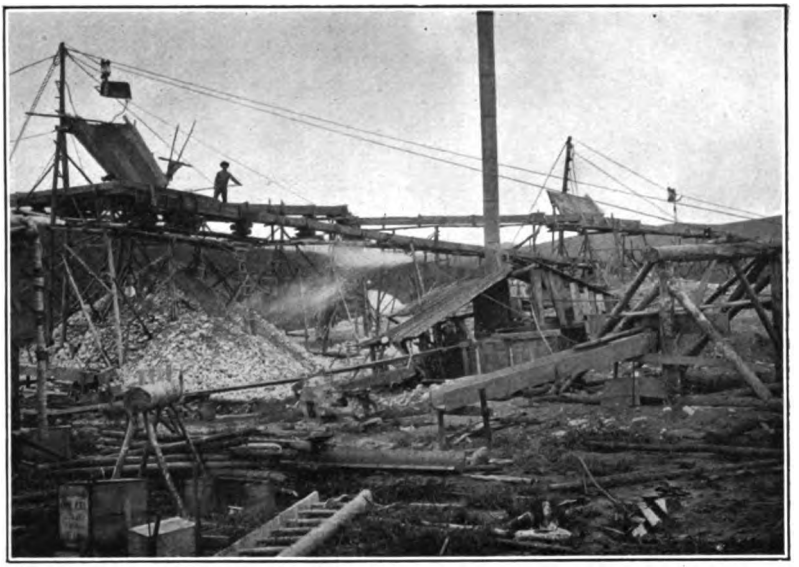

FIG. 41.—Modified Caribou undercurrent.

170 colors to the cent, the gold being worth $18.50 per ounce. No means of knowing the proportionate amount of this gold is possible, as with the methods at present employed very little of it is recovered. Five per cent is considered a fair average of the total gold represented by the above fineness of division. This gold, which is not flaky in spite of its fine character, could easily be saved with the proper appliances, and there is no doubt that much coarser gold is lost.

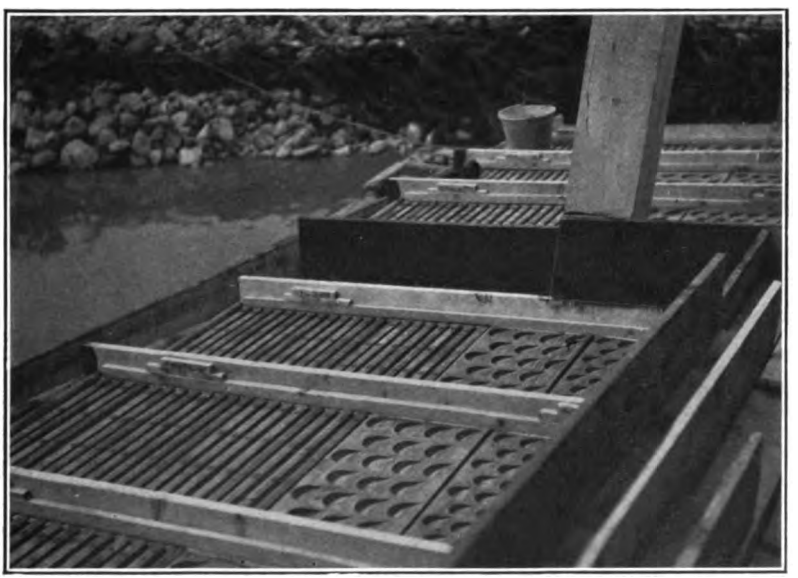
The question will be asked, Can a cheap and efficient washing plant be installed, where gravel must be elevated by power, which will not add greatly to the cost, and the parts of which can be easily and quickly made with the materials at hand?

On the principle that gold is best saved in the thinnest sheet of water which will carry the tailings away, it is evident that for fine gravel a wider sluice is better than a narrow one. In narrow sluice boxes,

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*A*. MUD BOX ON GOLD RUN, KLONDIKE.



*B*. OROVILLE RIFFLES USED AT ATLIN, BRITISH COLUMBIA.

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full or nearly full of water running with great velocity, fine gold will be carried along. Lengthening the sluice will not help matters. In fact, a short sluice with drops or undercurrent attachment is frequently more effective than a long sluice without it.

In a given case assume that the ordinary 14-inch boxes are widened to 24 inches, and that 5 boxes, with a grade of 9 inches to the box, fitted with the ordinary sapling-pole riffles, as at present, are succeeded by 3 boxes with the form of screen represented in fig. 41, the grade being made adjustable by means of blocking. An addition of 19½ inches to each of the 3 boxes would compensate for the loss of grade consequent on the uptilting of the screens. The whole drop in the string of boxes would be 103.5 inches as against 108 inches were 12 boxes used with 9-inch grade. Under the punched iron plates riffles of one or more kinds as described below, charged with quicksilver, should be used. The riffle shown in fig. 42 will be found satisfactory. Mats, plush, or blankets may under certain conditions be found more economical. A short transverse table following the last box, arranged under a grizzly from which the large material is discharged to the dump, will enable the operator to determine whether losses are occurring in the main sluice and screening boxes.

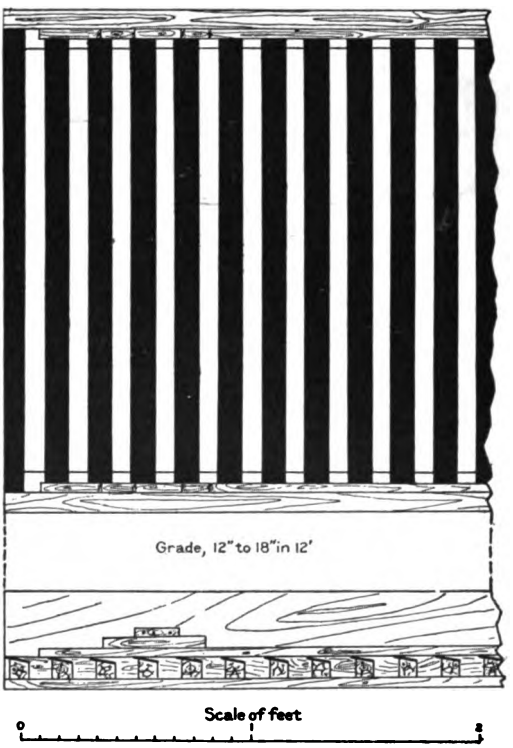



FIG. 42.—Improved Hungarian riffle used at Oroville.

The above installation is in principle a series of undercurrents combined in the main sluice. Its advantages of cheapness, adaptability to conditions, and simplicity recommend it. No extra power or water is required. On the other hand, the use of the mud box is not obviated.

Regarding the use of punched plates in working New Zealand gold-bearing marine deposits, Mr. H. W. Young[a] says:

The best size of perforation for hopper plates has been a matter for experiment by myself and others, variations from one-fourth inch to five-eighths inch having been put

[a] Report of New Zealand Minister of Mines, 1902, p. 21.

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to working tests. It is proved that holes of less than three-eighths inch diameter unduly limit the discharge through the plates, are liable to choke, and that there is no advantage whatever to be gained by their use. The discharge through seven-sixteenths inch holes is sufficient in amount, and the fine shingle particles which pass through with the sands and seldom exceed one-fourth inch in diameter are not troublesome in their size and quantity. In fact, many consider that they are of benefit in keeping lively the sands on the tables. With holes exceeding seven-sixteenths inch in diameter, the size and quantity of small shingle become excessive, and the water passes away so rapidly as to prevent material from being carried forward over the plates.

The above remarks are of somewhat general application for the use of punched iron screens in any form of undercurrent where it is assumed that a portion of the gold, including any nuggets which may occur,

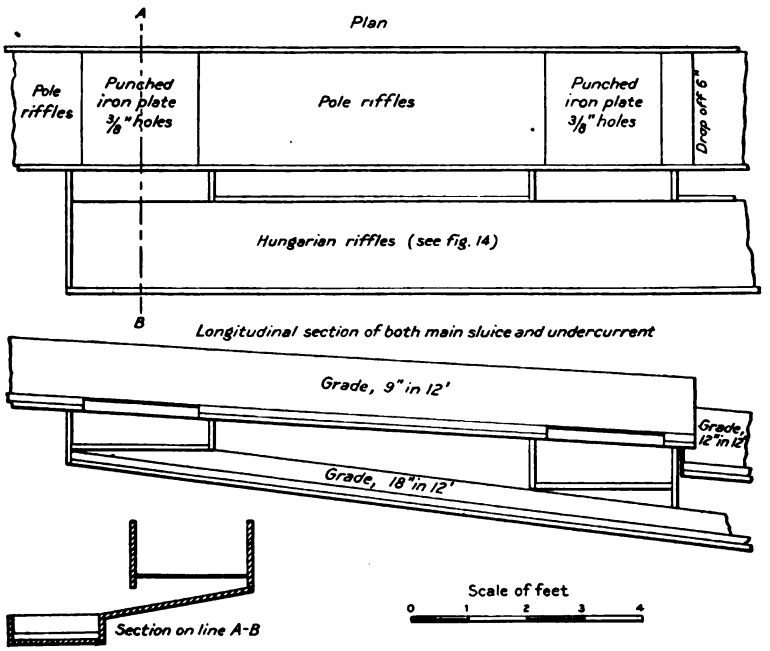



FIG. 43.—Kulibinka sluice and undercurrent used in Siberia.

has been previously saved. In northern deposits where dredges have been installed, as in the Klondike and on Stewart River, punched iron screens used in revolving trommels have large holes, up to 1½ inches, even when a tailings stacker is used, while the average size in Oroville dredging practice is three-eighths inch.

A screen installed in one box of the main sluice of a plant on Ophir Creek, Seward Peninsula, consisted of a number of longitudinally disposed round iron rods, acting as a grizzly, fitted above the bottom of the box, the gold being saved on mats below. This box, which was placed at the end of a 120-foot sluice, was said to save much fine gold.

When it is desirable to introduce the principle of the undercurrent,

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separate from the main sluice, the following device, adapted from one used in Siberia, as described by Mr. E. D. Levat,[a] may be adopted. Its capacity is given as 172 cubic yards per shift. The principle of the undercurrent is here introduced, but the discharge, of both coarse and fine, is to the same heap. This contrivance uses no power, and the method of handling accumulations of tailings will be more expensive than in plants already in use. Where the steam scraper is so generally employed, however, as in the Klondike for handling tailings, the innovation of the modified "kulibinka" here figured (fig. 43) would not add over $1,000 to the expense of installation, while the efficiency in saving the values would be greatly increased.

It has been shown that the Klondike sluice generally necessitates a man forking. The object of this forking is to take out the stones, from 6 to 18 inches in diameter, after their surface is washed. Mechanical devices for accomplishing this would be advantageous. Experience with gold dredges has proved that the revolving screen or trommel, inside of which play powerful jets of water, accomplishes this screening process most successfully. The trommel is, however, expensive, and its various parts and castings must be specially made at elaborately equipped works. Therefore it is worth while to consider whether simpler and cheaper devices will not accomplish nearly as good results for the Alaskan miner.

A plant to accomplish good washing results with sticky clay and gravel, and which can be built of materials at hand, is shown in fig. 44. This type of plant, founded on the idea of the Siberian pan, has a capacity of from 100 to 200 cubic yards in ten hours, and can be built in the winter months. Assuming that steam power is already at hand, it requires no outside material beyond the iron shoes and simple castings and the punched steel plate which forms the floor of the pan. Its operation will require 10 horsepower, and if the material is conveyed to it by the self-dumping carrier, the services of two men are sufficient to take care of the tailings. The machine will not only break up and thoroughly wash clayey gravel, but with properly arranged tables below will save the bulk of the fine gold which has been set free from its matrix. The cost of a pan of the dimensions here figured will not exceed $2,000, including the tables and sluices. The device for automatically clearing the bottom of the pan of large stones is not used in Siberia, where hand labor is cheap enough to dispense with it, the large stones being periodically removed by the lifting of gates in the periphery of the pan. The amount of water used in such a machine does not exceed ordinarily 125 miner's inches.

The drawing of this machine is made diagramatically, since the manner of its construction will depend on local conditions. A four-armed casting, keyed to the shaft and bolted to the horizontal timbers, is

[a] Levat, E. D., L'Or en Sibérie orientale, Paris, 1897.

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advisable. As used in remote districts in Siberia, the central shaft is frequently a wooden beam, and instead of the iron shoes, heavy stones dragged with chains, as in the arrastre, may supplant them.

The above suggestions are made with reference to working the rich gravels of the shallow northern placers. Gravel containing less than $2 to the cubic yard is rarely worked by the method of the cable and

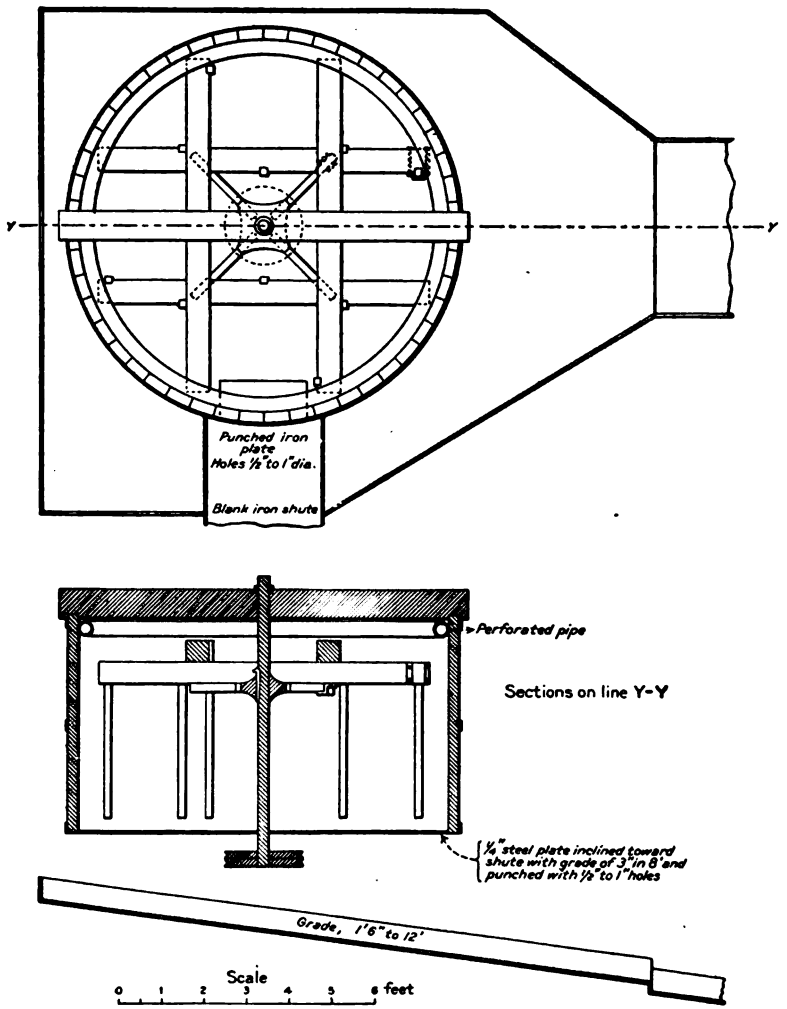



FIG. 44.—Modified Siberian pan for handling clayey gravel.

traveling bucket. Lack of natural grade makes it necessary that the miner shall elevate his material, and the impossibility of getting water under head makes the use of steam power imperative. The point is that when such elevation is attained, it should be made available to thoroughly wash the gravel. At present this is not done. Perhaps the suggestions here offered may be of benefit to some operators.

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In the construction of washing plants of a larger and more expensive kind, the operator has the benefit of the experience developed in gold dredging. This now rather important industry has brought into service devices for gold saving, in the use of which one of the main objects is to utilize to the best advantage all available vertical and areal space.

The employment of large mechanical excavators for placer mining has a field in the Northwest. Such operations necessitate one or more permanent washing plants to receive the gravel from each machine. It has been demonstrated that the dredge is the only form of excavator which can economically transport its sluices as it moves. Therefore a plant, situated as safely as possible with reference to danger from floods, and economically with reference to tramway, dump, and water supply, must be constructed frequently at a considerable expense.

The shaking screen, although it has received a thorough trial on gold dredges, does not find as much favor as the trommel. It is not impossible that modifications of the principle of the shaking screen and of the shaking table may be developed which will act more efficiently in saving gold than the trommel. Mr. Félix François[a] has recently figured and described a "shaking sluice-box" system of gold saving, for installation either in stationary washing plants or in dredges. He claims a very high percentage of saving, and as additional advantages the elimination of the use of quicksilver and the employment of a small amount of water. He does not give the cost of the plant, however, nor any actual results of its operation in practice.

The use of the trommel in a stationary washing plant is illustrated in Pl. XII, *A* (p. 80), a plant erected in the Klondike in connection with a steam shovel and incline operation. A short description of this plant is appended, but it should be understood that for the average miner the installation of such a plant is impracticable on account of first expense and the difficulty of getting the complicated machinery. The plant used 125 miner's inches of water, led by a ditch from Bear Creek; the capacity was said to be 500 cubic yards in ten hours. The material elevated to the platform at the upper end of the trommel was dumped into a hopper feeding the trommel. The water was led into the lower end of the trommel and fed through a perforated pipe. The largest holes in the revolving screen were 1 inch in diameter, and all oversizes passed through and into the hopper below the lower end, whence the tailings were hoisted in a self-dumping carrier, on a cable, for a horizontal distance of 200 feet and a vertical distance of 60 feet. The fines passed over 80 square feet of riffle tables, floored with expanded metal and cocoa matting, on a grade of 12 inches to 12 feet, followed by sluices with iron Hungarian riffles. Pl. XII, *B*, shows the

[a] Bull. Soc. de l'industrie minérale, vol. 8, 1894, p. 785.

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expanded-metal form of riffle table, which has given good satisfaction. The fines were, after passing out of the 96 feet of sluice boxes following the tables, elevated by a steam scraper to a pile 200 feet distant and 15 feet high. The expense of installation of such a plant will be not less than $5,000, and will more likely be $10,000 in any part of the interior of Alaska.

In arranging a number of gold-saving tables to receive the discharge from a screen, great care should be taken to distribute the material equally to these tables, so that the duty of each may be the same. This in the best Oroville practice is done by leading a small sluice trough from the main receiving sluice beneath the screen to each of the tables. In case of a second sizing, as in the Atlin dredge described below, the distribution is necessarily accomplished by a series of grizzlies in the main sluice. If small ducts or troughs are used, they should be provided with gates, the whole made of wood, like those used for distributing the pulp to the tables in concentrating mills. The attempt to distribute the fines directly from the trommel by means of iron gates is considered less satisfactory.

Riffles for the saving of fine gold in sluices are of many kinds and are of very ancient origin. Humboldt (Asie Centrale) refers to the

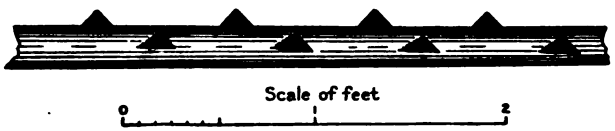



FIG. 45.—Pole riffle fitted with knives for breaking clay.

method in use of working the placers of Colchis—that of employing wool in the sluices—as a possible explanation of the legend of the "Golden Fleece." It was in fact known that the kings of Imeret in the eighteenth century used wool for collecting gold in Tskinitskali and Abacha rivers in the Caucasus, while Turkish gypsies use goatskin for gold saving on Belichta River.

The pole riffle made of saplings, with or without strap iron nailed to the top, has long been in favor in small placer operations in the United States, and is to-day employed in the primitive shoveling-in operations throughout the northern territory. An improvement on this riffle, simply made, aiding in the disintegration of clay, was seen by Mr. Frank L. Hess in the Rampart district of Alaska, and a sketch furnished by him is shown in fig. 45. Small squares of sheet iron one-sixteenth inch by 2 by 2 inches are driven cornerwise into the poles.

A development from the wooden pole riffle is the iron or steel rail, laid longitudinally in the sluice box. One type of rail riffle used in Seward Peninsula is shown in fig. 32. It will be noted that the T lies with its horizontal extension uppermost, that the rails are joined

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in gangs of four, and that a locking device is employed to prevent the gangs from coming up. Rail riffles of this kind are primarily intended for hydraulic operations and give excellent satisfaction, but can be recommended for creek placers only where the capacity warrants expensive installation.

At the present day the saving of fine gold is receiving marked attention on gold dredges, as the product of these machines frequently consists largely of gold in an exceedingly fine state of division. Fig. 42 and Pl. XXXVII, *B*, represent a sluice table now in use at Oroville, Cal. The grade of the table on the dredge at Atlin, British Columbia, is 12 per cent, corresponding nearly to 18 inches to 12 feet. These tables are set transversely beneath the main sluice, which is fed directly from the trommel, the main sluice having a grade of 12 inches to 12 feet. The quicksilver charge of the sluice and table is 200 pounds. The largest material passing over the sluice is 4 inches in diameter, while grizzlies do not permit over ½-inch sizes to go over the undercurrent tables. The total area of sluices and tables is from 600 to 1,000 square feet, from 500 to 700 miner's inches of water being used for an amount of material which will probably average 1,500 cubic yards per twenty-four hours.

The type of riffle here figured is used extensively at Oroville at present. It is stated by one of the operators who has experimented with the gold in that field, that from 15 to 20 per cent of the gold recovered with quicksilver, using this riffle, will pass 150-mesh sieve.

The expanded metal and cocoa matting riffle is also used with success at Oroville.

The Oroville gold contains a much larger proportion of fine colors than the northern fields. From the undercurrent sample of Klondike gold above described, assuming that this represents 5 per cent of the total recovery, screening tests appear to indicate that under 1 per cent of the Klondike gold, and under 2 per cent of the Fairbanks Creek gold, will pass 150 mesh.

The fineness of the gold on Sulphur Creek is shown by the table below:

*Fineness of gold from Sulphur Creek.*

| Mesh. | Per cent. |
|---|---|
| Under 150 | 10 |
| 150–100 | 60 |
| 100–80 | 20 |
| 80–60 | 10 |

Moreover. the gold, whatever its fineness of division, is generally round and shot-like and not flaky. Under such conditions, in view of the Oroville experience, losses such as undoubtedly occur in the northern practice are inexcusable.

The riffle shown in fig. 46 is designed to hold a divided sheet of quicksilver. Another form is made by boring 1½-inch augur holes to

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the depth of one-half inch. Some operators claim that a recurring quick jar imparted to the fine gold tables by means of an eccentric or other device aids the saving of the gold. The efficiency of this principle is questionable.

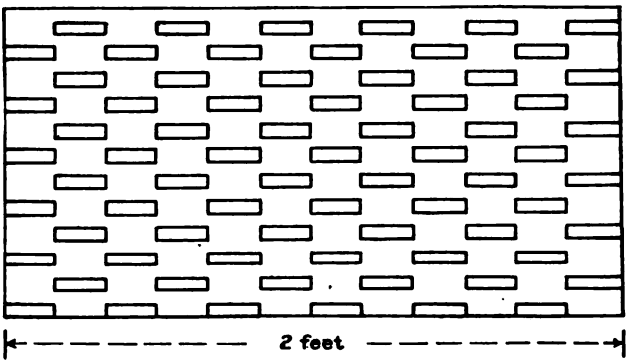



FIG. 46.—Riffle to hold divided sheet of quicksilver.

On the Snowflake claim, a bench claim, worked by drifting, situated between Anvil and Dexter creeks, much of the gold sluiced from the winter dump was porous, occurring in lumps one thirty-second to one-fourth inch in diameter, resembling dentist's gold. A peculiar riffle shown in fig. 47 was devised, consisting of sawn blocks nailed to riffle strips.

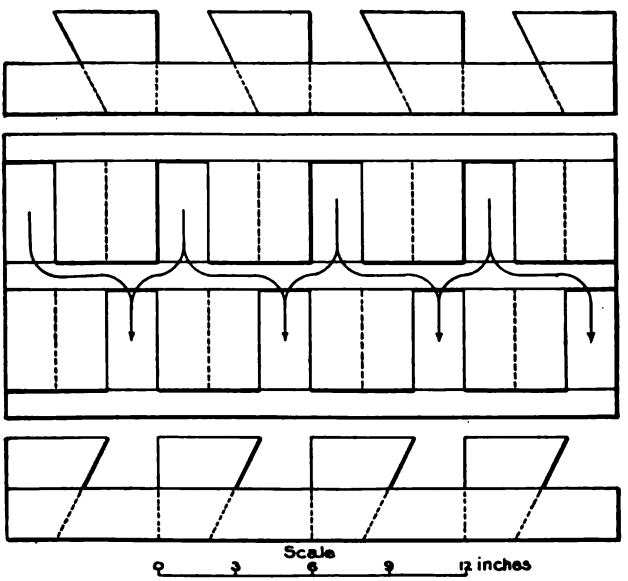



FIG. 47.—Special block riffle for saving porous gold.

This riffle used in 14-inch boxes, on 8-inch grade, with 50 miner's inches of water, was said to be the only one of many tried which would catch this gold.

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Fig. 48 shows an excellent iron riffle used in the smaller sluices of Seward Peninsula for saving gold of average fineness. The castings are light, can be easily handled, and can be set in the sluices so that the long dimension of the slots lies either transversely or longitudinally. The longitudinal arrangement has been found to be the better.

The use of quicksilvered copper plates is not likely to give increased saving in Alaska placer operations. Blankets, mats, or other fabrics are not generally used on account of their expense.

Mr. H. W. Young[a] has designed for the Waiwhero Sluicing Company, of New Zealand, a form of apparatus for the saving of fine gold which is used in New Zealand beach deposits where the gold is accompanied by an excessive amount of black sand. A few of Mr. Young's remarks are here quoted:

> The modern fine gold washing plant, as used on the West Coast, consists of three main essential parts. The first is the hopper box with stone shoot, which receives the water and gravels from the tailrace connecting with the sluicing face, and separates the stones and shingles from the water and sands. The second comprises the "sand box" or "boil box," with its discharge ducts and other accessories, intermediate between the hopper and the tables. The third comprises the washing tables and their accessories. The three essential parts deal with the stuff from the face, and reduce it to concentrated gold and heavy sand ready for amalgamation.

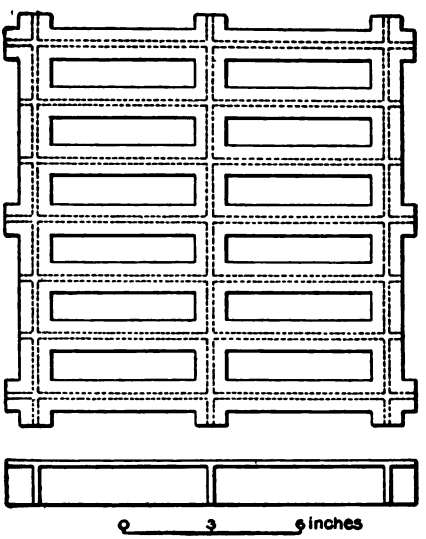



FIG. 48.—Iron-grate riffle, Seward Peninsula.

The introduction of a sand box or agitation box, in which the material is kept in agitation by being made to pass over and under a system of baffle boards before passing to the tables, as described by Mr. Young, is of obvious advantage in connection with the plant described. The principle will undoubtedly be of use in some of the washing plants of Alaska, as it provides a moderate stirring action without the use of mechanical power. The quantity of water economical for such a plant as the one described, with material screened to seven-sixteenths inch size on tables with a grade of 12 inches to 12 feet, is in the proportion of 40 miner's inches to each 10 feet of width of table. As at Oroville, the value of separate ducts from the feeding or sand box to each table has been proved.

The clearing of the gold from the accompanying minerals of high specific gravity is often difficult. In the creek workings on Bonanza

[a] Report of the New Zealand Minister of Mines, 1902, p. 20.

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Creek, Klondike, for example, of the total weight of gravel handled, 1 per cent of black sand, mostly magnetite, is caught with the gold in the clean-up. In American Creek, Alaska, the clean-ups are impeded by the presence of large quantities of barite pebbles. In the Fairbanks district red garnets and rutile, in some cases in quantity up to one-third of 1 per cent of the total material washed, are caught with the gold. In the Birch Creek district there is enough rutile in the auriferous sand to cause trouble in the clean-up. In Seward Peninsula the magnetite is in comparatively small amount. Garnets occur in the creek diggings up to 5 pounds to the cubic yard of gravel. In the beach and so-called "tundra" gold sands of the coastal plain from 3 per cent up to as high as 61 per cent of garnets occur.[a]

The use of quicksilver in the northern operations of America is limited. Even allowing for the extra expense and time consumed in the use and recovery of quicksilver, it is surprising that this important agency for saving fine gold is not more generally employed. It has been shown that the proportion of fine gold in the interior fields is large. The neglect to use quicksilver in attempting to save such gold can be considered only as a penny-wise-pound-foolish policy. It is needless to say that in all of the appliances above suggested for the saving of fine gold the use of quicksilver is imperative. Carelessness in the use of quicksilver, however, may result in increasing rather than diminishing the loss of fine gold. According to Bowie,[b] float quicksilver containing microscopic gold particles has been taken from the surface of the water 20 miles from the place where the amalgam entered the stream. A single flask of quicksilver is ample for the needs of the average creek operation of the Klondike or interior Alaska, and even with wasteful handling would last a season.

Whether quicksilver is used or not, it will be found advantageous to get the gold and amalgam as clean as possible on the floor of the sluices or tables before removing the valuable product. The comparatively small amount of heavy concentrates accompanying the creek gold of Seward Peninsula makes this possible in the frequent clean-ups of the tailrace. Skillful manipulation will accomplish the same result in the interior except where excessive quantities of magnetite occur. In one case on Bonanza Creek, Klondike, the fine concentrates which could not be removed with the magnetite after drying were skillfully separated by dry-panning.

Black sand or other concentrates have occasionally been found rich enough to pay for sacking and shipping to smelters after cleaning. Exaggerated reports of high assays in gold obtained from black sand frequently find credence. Nevertheless, whenever this concentrate

[a] Brooks, A. H., Mendenhall, W. C., Collier, A. J., and Richardson, G. B., Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900, U. S. Geol. Survey, 1901, p. 87.

[b] A Practical Treatise on Hydraulic Mining in California, 1885, p. 244.

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accumulates in the sluices or tables in any considerable amount, it should be sampled and assayed to ascertain the amount of finely divided gold which still remains in it.

## CLEANING, RETORTING, AND MELTING.

If amalgam is to be treated, it should be well stirred, either in buckets or large porcelain mortars, and the base material—sand, scraps of iron, etc.—which comes to the surface should be skimmed off.

This residue (which holds considerable amalgam) is concentrated by washing in pans or rockers, and the concentrations ground in iron (or porcelain) mortars and treated with more quicksilver. Any base material which floats on the surface of the bath is melted by itself to a base bullion. The remainder is added to the fine amalgam. The amalgam is strained from the quicksilver through drilling, and the dry amalgam is retorted in iron retorts.[a]

In cleaning the placer gold, when no quicksilver is used, a magnet inside a cotton sack passed through the dust will remove all the magnetite. Minerals of high specific gravity not attractable by the magnet are not easily removed by mechanical means. Rutile, garnets, and ilmenite are examples of these occurring in Alaska. In small operations the gold dust is roughly cleaned from these minerals by blowing and dry-panning. Where the amount of gold is considerable, a melting plant is advisable. In retorting amalgam, small hand retorts will in general be found adequate.

Before the amalgam is put in the retort the interior is coated with a thin wash of clay, which prevents the amalgam from adhering to the iron.

The amalgam should be carefully introduced and evenly spread. The iron pipe which connects the back end of the retort with the condenser must be clear of all obstructions, and under no circumstances should the amalgam be spread so that the pipe can possibly become choked, as in that case an explosion would probably ensue.

To avoid any danger arising from this source after the cover has been put on, lined with either clay or a mixture of clay and wood ashes, and securely clamped, the fire is lighted and the heat gradually raised, a dark-red heat being all that is necessary to thoroughly volatilize the quicksilver. Toward the end of the operation the heat is raised to a cherry-red color, at which it is kept until distillation ceases. The retort is allowed gradually to cool, and when cold is opened.[b]

A stream of cold water should be always flowing through the jacket which incloses the condensing pipe, so that by no possibility can mercurial vapor pass into the receiving vessel in which the lower end of the pipe terminates. The discharge end of the pipe should be kept under water during the retorting operation.

When gold accumulates in sufficient quantities to make the shipment of the dust inconvenient, the metal may be melted on the ground and molded into bricks. Both for convenience of shipment and facility in guarding against losses, this practice is to be recommended. A brief description of the essential features of this work follows.

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[a] Bowie, op. cit., p. 249. [b] Bowie, op. cit.

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In melting, a gasoline 2-jet furnace may be used. Gasoline under a pressure of 30 pounds enters a heating coil attached to the burner. The heating coil is so arranged and fed that liquid gasoline burning on the outside of the main feed vaporizes the gasoline which is used within the furnace. With the 30 pounds pressure used a very hot flame is the result. The gasoline supply should be stored without the building and brought in through pipes, so as to reduce the danger of explosion. An air barrel connected with the supply line and supplied with a small hand pump serves to keep the gasoline pressure as high as may be necessary. The furnace is made of sheet iron and lined with fire brick. A cover of asbestos and iron serves to retain heat. This should be so constructed as to allow the bolting on of new iron plates, as they burn off with the great heat generated. The operator should be supplied with asbestos gloves.

Crucibles are of various sizes. A No. 30 crucible, costing between $2 and $2.50, will hold from 900 to 1,000 ounces of impure gold or bullion with the necessary fluxing charge. They are composed of a mixture of fine clay and graphite, and to prevent breaking certain precautions should be observed. A new crucible should stand near the furnace, at least during two melts, and when first used should be heated gently. This precaution is not necessary when a crucible has once been used. After a crucible has been used five or six times it can not be depended on and it would be economy to discard it, as breaking during a melt is a source of great inconvenience and loss of time.

It is necessary to have an iron table near the furnace, upon which can be placed gold pans, shovels, tongs, etc.

Before the gold is placed in the crucible it should be accurately weighed and cleaned with a magnet, as above described.

In melting 900 to 1,000 ounces, three-fourths of a pound of borax should first be melted in the crucible as a flux. After the dust is poured in, one-fourth pound of soda with one-half pound of borax should be placed on top. The soda unites with the silica of the sand, but in perfectly clean gold is not needed. The borax unites with the iron occurring with the gold. When the dust is mixed with considerable iron pyrite it is well to add a small quantity of scrap iron. This, in uniting with the sulphur, forms iron sulphide, which comes off in the slag. If this precaution be not taken a hard matte, very difficult to remove, forms upon the brick.

During the melt it is necessary several times to skim the slag from the gold. A special instrument is used for this purpose, essentially a long rod bearing at its lower end an enlargement to which the slag will stick. After gathering a small quantity upon the skimmer it is brought out, and by rolling on the iron table is made into a smooth, disk-shaped mass upon the end of the rod. This operation is continued until the slag collected upon the skimmer becomes unwieldy, when it is cooled by plunging it in water and broken off. When the gold is

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reached it may be readily detected by its greater weight. A second flux of borax alone is then added, and when this has melted the product is ready for pouring.

A small crane to lift the crucible from the furnace and to pour the gold into the mold should be rigged overhead. Special tongs for lifting the crucible are made.

Though the mold should not be heated too much, it should always be raised to such a temperature that oil will burn on contact with it.

On removing the bullion brick from the mold it is placed in a pickle of three to four parts of water to one of nitric acid, which serves to clean the gold of surficial deposit. By using a hammer and a steel slag brush the brick is made ready for shipment.

## FINENESS OF GOLD.

The following table shows the fineness of Alaskan gold:

TABLE 13.—*Fineness of gold by districts and creeks.*

| District. | Fineness. | Authority. |
|---|---|---|
| Juneau: | *Per ounce.* | |
| Gold Creek | $17.50 | Operator. |
| Windfall Creek | 17.50 | Do. |
| Lemon Creek | 14.00 | Do. |
| Porcupine: | | |
| McKinley Creek | 16.80 | Members U. S. Geological Survey. |
| Porcupine Creek | 17.20 | Do. |
| Nizina: | | |
| Chittitu Creek | 18.71 | Operator. |
| Dan Creek | 18.87 | Do. |
| Chisna: | | |
| Miller Gulch | 18.41 | Do. |
| Slate Creek | 18.47 | Do. |
| Headwaters of Copper River | 17.80 | Do. |
| Sunrise: | | |
| Sixmile Creek | 17.34 | Members U. S. Geological Survey. |
| Crow Creek | 14.80 | Do. |
| Atlin: | | |
| Pine Creek | 16.43 | Operator. |
| Willow Creek | 15.65 | Do. |
| Spruce Creek | 16.50 | Do. |
| McKee Creek | 17.31 | Do. |
| Birch Creek | 16.23 | Do. |
| Gold Run | 16.00 | Do. |
| Klondike: | | |
| Bonanza Creek: | | |
| (*a*) High bench | 15.28 | Bank British North America. |
| (*b*) Creek | 16.43 | Do. |

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TABLE 13.—*Fineness of gold by districts and creeks*—Continued.

| District. | Fineness. | Authority. |
|---|---|---|
| Klondike—Continued. | | |
| Hunker Creek: | *Per ounce.* | |
| (*a*) Bench | $17.75 | Bank British North America. |
| (*b*) Creek | 17.46 | Do. |
| Dominion Creek | 16.93 | Do. |
| Gold Run | 17.53 | Do. |
| Sulphur Creek | 16.48 | Do. |
| Bear Creek | 14.61 | Do. |
| Last Chance Creek: | | |
| (*a*) Bench | 14.12 | Do. |
| (*b*) Creek | 15.35 | Do. |
| Fortymile: | | |
| Wade Creek | 17.72 | Do. |
| Walker Fork | 18.03 | Operator. |
| Chicken Creek | 17.54 | Do. |
| Stone House Fork | 17.40 | Do. |
| Irene Gulch | 17.40 | Do. |
| Eagle: | | |
| American Creek | 17.61 | Bank British North America. |
| Mission Creek | 17.57 | Do. |
| Circle district: | | |
| Deadwood Creek | 16.73 | Do. |
| Mastodon Creek | 17.00 | Operator. |
| Mammoth Creek | 17.38 | Do. |
| Miller Creek | 17.25 | Do. |
| Eagle Creek | 18.93 | Bank British North America. |
| Mastodon Fork | 18.50 | Operator. |
| Woodchopper Creek | 18.32 | Do. |
| Fairbanks: | | |
| Fairbanks Creek | 17.76 | Bank British North America. |
| Cleary Creek | 17.24 | Do. |
| Pedro Creek | 18.40 | Operator. |
| Chatham Creek | 17.60 | Bank British North America. |
| Twin Creek | 18.40 | Operator. |
| Rampart: | | |
| Little Minook Creek | 19.24 | Bank British North America. |
| Little Minook, jr., Creek | 19.00 | Members U. S. Geological Survey. |
| Hunter Creek | 19.00 | Do. |
| Baker Creek | ---------- | |
| (*a*) Bench | 14.88 | Do. |
| Thanksgiving Creek | 15.17 | Do. |
| Glen Gulch | 16.00 | Operator. |
| Gold Run | 16.00 | Do. |

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TABLE 13.—*Fineness of gold by districts and creeks*—Continued.

| District. | Fineness. | Authority. |
|---|---|---|
| Nome: | *Per ounce.* | |
| Anvil Creek | ..... | |
| (*a*) Bench | $18.60 | Bank of Cape Nome. |
| (*b*) Creek | 18.75 | Do. |
| Glacier Creek | 18.60 | Do. |
| Dexter Creek | 18.60 | Do. |
| Dry Creek | ..... | |
| (*a*) Creek | 18.39 | Operator. |
| (*b*) Bench | 17.30 | Do. |
| Beach diggings | 17.98 | Bank of Cape Nome. |
| High benches | 18.70 | Do. |
| Grass Gulch | 18.60 | Do. |
| Peluck Creek | 18.19 | Do. |
| Hastings Creek | 18.19 | Do. |
| Basin Creek | 18.00 | Operator. |
| Bonanza Gulch | 18.59 | Do. |
| Council: | | |
| Ophir Creek | 18.49 | Bank of Cape Nome. |
| Crooked Creek | 18.49 | Do. |
| Mystery Creek | 18.70 | Do. |
| Solomon: | | |
| Solomon River | 18.60 | Do. |
| Big Hurrah Creek | 18.39 | Do. |
| Port Clarence: | | |
| Gold Run Creek | ..... | |
| (*a*) Bench | 18.35 | Operator. |
| (*b*) Creek | 18.55 | Do. |
| Anikovik River | 19.00 | Do. |
| Sunset Creek | 17.50 | Do. |
| Fairhaven: | | |
| Bear Creek | 19.20 | Members U. S. Geological Survey. |
| Hannum Creek | 18.25 | Do. |
| Inmachuk River | 18.39 | Bank of Cape Nome. |
| Candle Creek | 17.77 | Do. |
| Kougarok: | | |
| Gold Run | 18.39 | Do. |
| Alder Creek | 18.39 | Do. |
| Kougarok River | 18.60 | Do. |
| Homestake Creek | 18.75 | Operator. |



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## LABOR.

The following table (14) shows the average wages paid for labor in the mining districts of Alaska and adjacent Canadian territory during the summer of 1904. When the prices for winter work were available such have been added. The prevailing wages have been placed under the names of the districts as these are generally known, it being understood that the name of the nearest town, as, for example, Nome, stands for the creeks in the vicinity. Timbermen, carpenters, blacksmiths, and others whose pay is generally higher than that of ordinary laborers in the United States, are rarely paid more in Alaska. In districts where steam-thawing methods are employed engineers include pointmen. Hoistmen are not classed as skilled laborers, and where special prices for engineers obtain the men are usually in charge of large engines or pumps.

Two shifts are worked on most of the mines, especially in the summer. In hydraulic operations at night only one-third or one-fourth as many men are employed as on the day shift. In steam-thawing operations, where thawing is done at night, one or two pointmen and a fireman on the night shift generally take care of all the thawing, which will employ from 10 to 20 men in excavating, tramming, hoisting, and washing during the following day shift.

Ten-hour shifts are the rule throughout the northern placer fields. In large hydraulic operations the pipemen, as in other regions, generally work twelve hours. At only a few places were men seen working an eight-hour shift. At one of these, where men were shoveling into sluice boxes, it was proved by actual measurement of the ground that the number of yards shoveled per shift per man was greater than on adjacent claims where ten-hour shifts were in practice. In one instance on Ophir Creek, in Seward Peninsula, two eleven-hour shifts were worked, the men being paid 50 cents an hour and board. Experience has proved that the eight-hour shift for hard physical work is most economical in the operations in Alaska, where a large number of men are employed in shoveling and where every moment of the short season is valuable, and it would seem that the division of labor into three shifts of eight hours cheapens rather than increases the cost of handling material.

In some of the camps of Seward Peninsula a hospital fee of $2 per man per month is charged. This gives the laborer the services of a competent physician in case of sickness. Alaska is a singularly healthy country at all times of the year, and, although detailed statistics are not available, the proportion of deaths and illness to the total population would seem to be remarkably small.

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TABLE 14.—*Scale of wages in Alaskan camps, including Dawson, Yukon Territory, and Atlin, British Columbia.*

| | Laborers. | Foremen. | Engineers. |
|---|---|---|---|
| Juneau | $3.50 to $4, without board; pipemen, $5. | $5, without board. | $5 a day, without board. |
| Chisna | $5 to $10 a day; some $12.50; some $90 to $150 per month. | | |
| Nisina: | | | |
| Copper Creek | $100 a month and board | | |
| Dan Creek | $7.50 a day | | |
| Sunrise | $4 a day, no board | | |
| Porcupine | $3 and board | $4 and board | |
| Atlin | $3.50 to $4.50 and board; $5 to $6.50, (pipemen), without board. | | $4 and board. |
| Dawson | $3.50 to $5 and board; winter, $3 and board. | $10 a day, no board. | $4 to $6 and board. |
| Fortymile | $5 and board; $8, no board. | | |
| Eagle | $5 and board | | |
| Rampart | $5 a day and board | | |
| Birch Creek: | | | |
| Deadwood Creek | $10 a day, no board | | |
| Birch Creek | $8 a day, no board; $6 to $8 a day, no board, is average. | | |
| Fairbanks | $10 a day, no board, general wages. | $14 a day, no board; some $6 and board; some $10 and board. | $12, no board; some $8 and board. |
| Some claims on Cleary Creek. | $5 and board | | |
| Some claims on Fairbanks Creek. | $6 and board | | |
| Nome | Summer, $5 a day and board; winter, $2.50 a day and board. | | $180 to $200 a month and board. |
| Council | Summer, $5 a day and board; winter, $3 a day with board. | $10 a day and board. | |
| Solomon | $5 and board | $7.50 and board. | |
| Kugruk | $6 a day and board | | |
| Fairhaven | $5 and board; some at $100 per month. | | |
| Port Clarence | $5 a day and board; $8 without board. | | |

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## LUMBER AND FUEL.

### TIMBER.

The areal distribution of timber in Alaska does not by any means coincide with that of the placer gold. The South Coast region, in which there are extensive forests,[a] does not contain the most extensive alluvial gold deposits. The Juneau, Porcupine, and Sunrise districts are the only placer-gold fields developed within the area of heavy timber. In these three districts the large timber may be taken advantage of for local use. Under present conditions of transportation, however, this coastal timber forms no more of an asset in the consideration of the interior and the Seward Peninsula placer fields than as if it did not exist.

Spruce is commonly the timber on which the gold miner of the interior has to rely. It is very poor, both for fuel and for lumber, and in steam-producing quality a cord is the equivalent of not more than 700 pounds of Pennsylvania bituminous coal. The diameter of the spruce of the interior Yukon Valley rarely exceeds 18 inches, and averages 10 inches. The timber line varies from 2,000 to 3,000 feet above the sea, and many of the low-lying river valleys are fairly well forested. In the Tanana Valley and its tributaries near Fairbanks is found an exceptionally good growth of spruce timber, up to 18 inches in diameter, while birch, aspen, and cottonwood occur in less amount.

In the Fortymile district spruce trees up to 18 inches in diameter occur, but in general the growth does not differ from that found along the Yukon and Tanana bottoms.

At the head of the Tanana and White rivers the timber line reaches 3,000 feet, and there is a fairly good growth of spruce, birch, aspen, and cottonwood. The Kuskokwim and Koyukuk River valleys are also timbered with spruce.

The Sunrise and Chisna districts, which are nearer to the coastal strip than the regions mentioned above are better supplied with timber, spruce from 18 to 24 inches being common.

Those portions of Seward Peninsula which have attained importance from a placer-mining standpoint possess no timber except stunted willows. All mining operations must therefore depend on a foreign supply.

The prices for lumber in table 15 are for native or imported lumber, according to the timber resources of the district. In general all the interior camps make use of the native lumber. One of the difficulties experienced is to get good clear bottom boards for sluice boxes.

Sawmills are in operation at all the principal centers, Atlin, Dawson, White Horse, and Fairbanks. At Central House in the Birch Creek

[a] Brooks, A. H., The geography and geology of Alaska: Prof. Paper U. S. Geol. Survey No. — (in preparation), forestry map, Pl. —.

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district a sawmill was formerly in operation, but has been abandoned. At Fairbanks, in the summer of 1904, two sawmills with a total daily capacity of 25,000 board feet were in operation.

Timber fires are frequent in the interior and are sometimes very destructive in dry seasons. There being no system of policing the forests for purposes of fire protection, the probability is that an increasingly large amount of timber will, as the population increases, be annually destroyed by fire.

## COAL.

Though there are extensive[a] coal fields in Alaska, practically none of them have been exploited. Much of the coal is of a lignitic character, but some very good bituminous coals have been found. In the South Coast province good coal occurs 20 miles from the coast near Controller Bay[b] and in the Matanuska basin[c] 50 miles from the head of Cook Inlet. Neither of these fields are yet within reach of transportation. Lignitic coals are present at many localities along the Pacific coast, but these, too, are undeveloped.

In the interior coal has been mined along the Yukon, but has not yet furnished a local fuel supply. The Yukon[d] coals include the lignite beds of the upper river and a better grade of bituminous coals which outcrop along the Yukon below Nulato. Lignite coal has also been found along the Koyukuk and on the Cantwell, a southern tributary of the Tanana. Though these coals may in the future furnish fuel for placer-mining operations they are an unknown factor.

Lignite has been found in the eastern part of Seward Peninsula, but its commercial value is unproved. A small mine has, however, been in operation in the Fairhaven district near Kotzebue Sound,[e] and has found a ready market for its output, which is of a lignitic character.

Near Cape Lisburne, 200 miles north of Nome,[f] bituminous coal occurs in commercial quantities, but has not yet been mined to any extent. It is still an open question whether it can compete with the imported coals.

The fuel question in Alaska may take a new phase with the introduction of gas-producing engines, for these lignites are found to be very effective power producers.

The following brief statement concerning recent tests with the gas producer at the United States Geological Survey coal-testing plant,

[a] Brooks, A. H., The coal resources of Alaska: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 8, 1901, pp. 515–571.

[b] Martin, G. C., Petroleum fields of Alaska and Bering River coal fields: Bull. U. S. Geol. Survey No. 225, pp. 371–376.

[c] Stone, R. W., Coal resources of southwestern Alaska: Bull. U. S. Geol. Survey No. 259, pp. 151–171.

[d] Collier, A. J., The coal resources of the Yukon: Bull. U. S. Geol. Survey No. 218.

[e] Moffit, F. H., The Fairhaven gold placers, Seward Peninsula, Alaska: Bull. U. S. Geol. Survey No. 251, p. 67.

[f] Collier, A. J., Coal fields of the Cape Lisburne region: Bull. U. S. Geol. Survey No. 259, pp. 172–185.

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St. Louis, has been courteously furnished for this report by Mr. Marius R. Campbell:

The results of tests made during the past season at the United States Geological Survey coal-testing plant at the Louisiana Purchase Exposition at St. Louis proved conclusively that producer gas of such a quality that it may be used directly in a gas engine can be made from bituminous coals and lignites as well as from the highly carbonized fuels, such as anthracite, coke, charcoal, and wood, that alone have been used in the past for this purpose, and strange as it may appear, the lignites and lignitic coals have yielded better results than those ordinarily classed as bituminous. This means that the low-grade coals of the western half of the United States may have a value for the production of power equal to that of the best West Virginia coal as it is used at the present time.

The equipment by which these results were obtained consists of a Taylor gas producer with economizer, scrubber, tar extractor, purifier, and gas holder, furnished by R. D. Wood & Co., of Philadelphia, and a gas engine of 235 B. H. P., furnished by the Westinghouse Machine Company, of Pittsburg. The great difficulty in the past in using bituminous coals in the producer has been the extraction of the tarry matter from the gas. With the above equipment the tar and sulphur in the gas is almost completely removed, so that these substances give little or no trouble in the gas engine.

It appears, then, that the interior must for the present depend for fuel on its timber resources, such as they are. The camps of Seward Peninsula will probably adopt crude oil as the most economical fuel if the price can be brought down to $2 a barrel delivered at Nome. There appears to be a need at Nome and some of the other large camps of an oil-tank and pipe-line system by which the oil can be cheaply transferred from steamers, stored, and pumped to the various producing creeks adjacent to the coast. The native spruce timber will afford a fuel supply to the region east of Niukluk River, if gold discoveries are made there.

For any of the camps in the South Coast region there is an abundant supply of fuel, as wood may be had for the cutting, and coal can be had at a comparatively low cost.

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TABLE 15.—*Cost of firewood and flume lumber in Alaskan camps, including Dawson, Yukon Territory, and Atlin, British Columbia.*

| | Fuel. | Lumber per M, planed on one side unless otherwise stated. |
|---|---|---|
| Juneau district: | | |
| Windfall Creek | | $10.00 |
| Gold Creek | | 12.50–15.00 |
| Chisna district: | | |
| Headwaters of Copper River | | 150.00 |
| Slate Creek | | 150.00 |
| Daisy Creek | | 150.00 |
| Nizina district: | | |
| Chititu Creek | | 100.00 |
| Copper Creek | | 150.00 |
| Dan Creek | | 150.00 |
| Sunrise district: | | |
| Crow Creek | | 25.00–35.00 |
| Resurrection Creek | | 25.00 |
| Porcupine district: | | |
| Porcupine Creek | | 20.00 |
| McKinley and McCoon creeks | | 50.00 |
| Atlin district: | | |
| Pine Creek | | 40.00–50.00 |
| Boulder Creek | Spruce wood, $7 cord | |
| Spruce Creek | | 40.00–50.00 |
| McKee Creek | | 35.00–40.00 |
| Birch Creek | | 35.00–40.00 |
| Dawson district: | | |
| Bonanza Creek | Spruce wood, $15 cord | 70.00–90.00 |
| Eldorado Creek | | |
| Gold Run | Spruce wood, $9 cord | 70.00–100.00 |
| Sulphur Creek | Spruce wood, $9.50 cord | 80.00 |
| Upper Dominion Creek | Spruce wood, $11.50 cord | |
| Hunker Creek | Spruce wood, $11 cord | 60.00–90.00 |
| Fortymile district: | | |
| Wade Creek | | [a] 175.00 |
| Walker Fork | | [a] 100.00 |
| Chicken Creek | | 200.00–250.00 |
| Eagle district: | | |
| American Creek | | [a] 75.00 |
| Discovery Fork | | |
| Rampart district: | | |
| Gold Run Creek | | 120.00 |

[a] Rough.

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TABLE 15.—*Cost of firewood and flume lumber in Alaskan camps, etc.*—Continued.

| | Fuel. | Lumber per M, planed on one side unless otherwise stated. |
|---|---|---|
| Circle district: | | |
| Deadwood Creek | Spruce wood, $12 cord | $100.00–125.00 |
| Independence Creek | | |
| Mastodon Creek | | 125.00 |
| Mammoth Creek | | |
| Eagle Creek | Spruce wood, $10 cord | 180.00 |
| Miller Creek | | |
| Woodchopper Creek | | 70.00 |
| Fairbanks district: | | |
| Fairbanks Creek | Spruce wood, $10 cord | 220.00–250.00 |
| Cleary Creek | | 225.00 |
| Chatham Creek | Spruce wood, $10 cord | 225.00 |
| Pedro Creek | Spruce wood, $7 cord | 100.00–150.00 |
| Gold Stream | Spruce wood, $7 cord | |
| Nome district: | | |
| Anvil Creek | Bituminous coal from $17 to $30 per ton. | 50.00 |
| Dexter Creek | | 50.00–60.00 |
| Glacier Creek | | 50.00–60.00 |
| Bourbon Creek | Crude oil at Nome, $3 per barrel. | |
| Dry Creek | | 45.00 |
| Peluk Creek | Gasoline distillate at Nome, $3.50 per 10-gallon case. | 50.00 |
| Basin Creek | | 70.00 |
| Council district: | Wood, $12 cord on the Niukluk River. | |
| Ophir Creek | | 60.00–100.00 |
| Melsing Creek | | |
| Crooked Creek | | 125.00 |
| Solomon district: | | |
| Solomon River | | |
| Kassan Creek | | |
| Kougarok district: | | |
| Homestake Creek | | 150.00 |
| Fairhaven district: | | |
| Candle Creek | | 100.00–150.00 |
| Inmachuck River | | 70.00 |
| Kugruk River | | 150.00 |
| Port Clarence district: | | |
| Anikovik River | | 60.00 |
| Gold Run | | 125.00 |
| Buck Creek | | 50.00 |

[a] Rough.

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## ROADS AND ROAD BUILDING IN ALASKA.

### INTRODUCTION.

The means of getting from one part of the Territory to another and from the various towns and supply points to their tributary mining camps are very bad. The data concerning road construction, which were courteously furnished me by officers of the Canadian government based on Klondike experience, indicate that road building on an extensive scale is entirely feasible in the northern latitudes, and that roads can be constructed and maintained at moderate cost. In all probability Alaska is worse equipped with those improvements which contribute to progress and prosperity than any other area of like size lying in the domain of a civilized people.

Highway construction in Alaska is of the highest importance to the development of the Territory. The product of the gold-bearing gravels which have been already exploited is sufficient to support a considerable number of persons and to maintain towns of important size. The gold mining which has been done in the interior of Alaska has been conducted in spite of difficulties of transportation which would hardly be credible were they not substantiated by figures obtained in many parts of the Territory from responsible men.

It must not be assumed that the ordinary miner of Alaska is of a provident disposition. Many men of great energy, to whom is due the credit of having developed and opened large portions of this hostile country, are little disposed to take care for the future; yet they possess pluck and determination which is deserving of the highest praise. Outside of geologic and topographic exploration and making of excellent maps, and the furnishing of postal and telegraphic service, the miner, until the present session of Congress (1905), has been very little assisted.

An act of Congress was passed April 27, 1904, authorizing the appointment of road overseers and the creation of road districts in the Territory of Alaska, but this proving impracticable after a year's trial Congress has met the urgent demands for road building by the recent enactment of a statute which in two of its sections provides for the limited building and maintenance of wagon roads and trails.[a] Following are the first two sections of the said act:

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That all moneys derived from and collected for liquor licenses, occupation, or trade licenses outside of the incorporated towns in the district of Alaska shall be deposited in the Treasury Department of the United States, there to remain as a separate and distinct fund, to be known as the "Alaska fund," and to be wholly devoted to the purposes hereinafter stated in the district of Alaska.

[a] An act to provide for the construction and maintenance of roads, the establishment and maintenance of schools, and the care and support of insane persons, in the district of Alaska, and for other purposes.

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One-fourth of said fund, or so much thereof as may be necessary, shall be devoted to the establishment and maintenance of public schools in said district; five per centum of said fund shall be devoted to the care and maintenance of insane persons in said district, or so much of said five per centum as may be needed; and all the residue of said fund shall be devoted to the construction and maintenance of wagon roads, bridges, and trails in said district.

SEC. 2. That there shall be a board of road commissioners in said district, to be composed of an engineer officer of the United States Army, to be detailed and appointed by the Secretary of War, and two other officers of that part of the army stationed in said district, and to be designated by the Secretary of War. The said engineer officer shall during the term of said detail and appointment abide in said district. The said board shall have the power and it shall be their duty, upon their own motion or upon petition, to locate, lay out, construct, and maintain wagon roads and pack trails from any point on the navigable waters of said district to any town, mining or other industrial camp or settlement, or between any such town, camps, or settlements therein, if in their judgment such roads or trails are needed and will be of permanent value for the development of the district; but no such road or trail shall be constructed to any town, camp, or settlement which is wholly transitory or of no substantial value or importance for mining, trade, agriculture, or manufacturing purposes. The said board shall prepare maps, plans, and specifications of every road or trail they may locate and lay out, and whenever more than five thousand dollars in the aggregate shall have been expended on the construction of any road or trail, contract for the work shall be let by them to the lowest responsible bidder, upon sealed bids, after due notice, under rules and regulations to be prescribed by the Secretary of War. The board may reject any bid if they deem the same unreasonably high, or if they find that there is a combination among bidders. In case no responsible and reasonable bid can be secured, then the work may be carried on with material and men procured and hired by the board. The engineer officer of the board shall in all cases supervise the work of construction and see that the same is properly performed. As soon as any road laid out by the board has been constructed and completed they shall examine the same and make a full, detailed report of the work done on the same to the Secretary of War, and in such report they shall state whether the road or trail has been completed conformable to the maps, plans, and specifications of the same. It shall be the duty of said board, as far as practicable, to keep in proper repair all roads and trails constructed under their supervision, and the same rules as to the manner in which the work of repair shall be done, whether by contract or otherwise, shall govern as in the case of the original construction of the road or trail. The cost and expenses of laying out, constructing, and repairing such roads and trails shall be paid by the Secretary of the Treasury out of the road and trail portion of said "Alaska fund" upon vouchers approved and certified by said board. The Secretary of the Treasury shall, at the end of each month, send by mail to each of the members of said board a statement of the amount available of said "Alaska fund" for the construction and repair of roads and trails, and no greater liability for construction or repair shall at any time be incurred by said board than the money available therefor at that time in said fund. The members of said board shall, in addition to their salaries, be entitled to receive their actual traveling expenses paid or incurred by them in the performance of their duties as members of said board.

It will be of interest to state that during the twelve months ending June 30, 1904, the total amount collected from license fees outside of incorporated towns was $145,043.65.[a]

[a] MacLennan, M. F., Receipts and disbursements of the United States for the fiscal year ending June 30, 1904, Treasury Department, p.14.

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As a little less than three-fourths of this amount is available for roads, it is evident that the work can not be pushed very rapidly.

It is probable that not more than 40 miles of standard road could be built and maintained in any one year in the central Yukon province, and not more than 20 miles of standard road in the South Coast province. Moreover, it is not likely that the fund will increase rapidly, as the number of incorporated towns is growing.

Though a beginning was made in the construction of a military horse trail from Valdez over Thompson Pass, the project was only partially successful on account of lack of funds for maintenance.

The recommendation of Mr. Alfred H. Brooks, of the Geological Survey, of an appropriation of $1,000,000 to be spent for wagon roads in Alaska is amply justified by the necessities of the case. It is probable that for this sum 900 miles of roads (300 of the Dawson standard wagon type and 600 for sleds) could be built in those parts of the country which would be most assisted by their construction. Provision should, however, be made for their annual maintenance. The inhabitants of Alaska would be as appreciative of such Federal aid as those of any portion of the American possessions, and, by such improvement in transportation facilities, the annual Alaskan product in gold would be greatly increased.

A serious detriment to the making of a road in Alaska is the thawing of the ground beneath the moss. It has been the universal experience that wherever the moss is cut into thawing immediately commences, and the trail which was passable becomes a filthy, slimy mass of mud, roots, and broken stones, a difficult route for men on foot, a slow and tiresome road for loaded animals, and an impassable obstacle to any sort of vehicle. In regions farther south, under temperate conditions, trails frequently are developed into fair wagon roads by much usage. Such developments can never take place in any part of the Northwest.

In the Northwest, where the ground is always subject to slight disturbances from alternate freezing and thawing, the roads can not be as durably constructed as in portions of the United States where similar topographic conditions prevail. The table of expenses furnished by the Canadian government for this report shows that the cost of maintenance does not exceed 15 per cent of the original mile-cost of the road. A feature that can not be too strongly impressed on those who have never seen the interior of Alaskan country is the extraordinary difference between the topography of the southeast coast, which is most often visited by tourists, and the portions of the country in which the rich placer deposits have been developed. In the coast region about Juneau, Admiralty and Baranoff islands, and in Prince William Sound (see Pl. XVI, *A*, p. 114) the needle-like peaks, precipitous slopes, cataracts in summer, avalanches in winter, and all the

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formidable conditions characterizing an alpine district make road building very costly. There is much rock work, and expensive bridges, trestles, and culverts are necessary. The cost of the wagon road from Juneau into Silver Bow basin was $3,750 a mile, and that of the wagon road built in 1898 from Skagway to the summit of the White Pass was $6,000 per mile. Compare this with the Yukon-Tanana gold district. In the vicinity of Fairbanks 13 miles of passable wagon trail, over what is known as the Ridge Trail going to the creeks, have been built at a cost of less than $100 per mile.[a] This road (see Pl. XXXVIII, *A*) was made through a stretch of birch and aspen timber; the trees were cut out and many of the stumps removed; no ditch was made along the sides and the road was wide enough for only one wagon. But it is passable, and freight rates have already been reduced from 25 and 30 cents per pound to 10 and 15 cents.

It may be objected that transportation sufficient to meet the needs of the miner can be accomplished in winter when the freight rates are very much cheaper. This is far from being the case. The winter transportation itself would be greatly assisted by good roads on which sleds of 4 and 5 ton capacity could travel. As to winter freighting, it may be stated that in the winter of 1903 a man contracted to transport a boiler weighing 5,600 pounds from the town of Fairbanks to Pedro Creek, a distance of 20 miles, for $2,000, and lost $300.

Furthermore, 75 per cent of the work of exploiting the gold-bearing gravels is carried on in the four months of the open season, and then the miners are in need of the bulk of their supplies. In summer the prices of commodities in the towns are frequently lower than in winter. The period during which supplies for the winter are generally brought in is from August 1 to September 1.

### COST AND METHOD OF CONSTRUCTING HIGHWAYS.

Considered from a highway standpoint, Alaska, owing to its varying topography and natural conditions, may be divided into three provinces—the South Coast province, the central Yukon province, and the Seward Peninsula province. Opportunity was had to inspect the excellent wagon roads which have been built in the northwest portion of Canada by the Canadian government. The figures courteously given by the officers of the Canadian department of public works relative to the cost of highway construction in the Yukon Territory are considered representative of the probable cost of such construction in the central Yukon province of Alaska. This and other information is embodied in table 16, and portions of it are elaborated in the succeeding paragraphs. The object of the table is to show, in a form easy for comparison, the costs of road building in the Northwest as exemplified by and estimated from previous experience.

[a] So low a cost would not have been possible had not teamsters hauled all necessary supplies gratis.

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*A*. ROAD IN FAIRBANKS DISTRICT.



*B*. ROAD IN ATLIN DISTRICT, BRITISH COLUMBIA.

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The portions of Alaska represented by Alaska Peninsula and neighboring islands, and the Copper River basin, north of Prince William Sound, have not been especially considered, as there appears to be no present need there of expensive routes of communication. In general it may be said, however, that the cost of construction in Alaska Peninsula is the same as in Seward Peninsula, and the cost in the Copper River basin the same as in the central Yukon province.

TABLE 16.—*Cost of road construction.*

| Locality. | Authority. | Construction, cost per mile. | Annual maintenance, cost per mile. | Notes. |
|---|---|---|---|---|
| South Coast province: | | | | |
| Juneau | Private constructors. | $3,750 | ..... | Good road built under great topographic difficulties. |
| Skagway—White Pass. | .....do ..... | 6,000 | ..... | Road no longer used. |
| British Columbia: | | | | |
| Atlin | B. C. Atlin, gold commissioner. | 300–1,000 | ..... | Good roads easily built, very little corduroy. |
| Yukon Territory: | | | | |
| Dawson and vicinity. | Canadian department of public works of Yukon Territory. | 1,500–3,300 | $350 | Standard highways constructed as described below. |
| Do | .....do ..... | 250–350 | 25 | Sled or winter trails; rarely used in summer. |
| Seward Peninsula: | | | | |
| Nome and vicinity. | Estimates based on cost of railways already constructed. | 3,000–4,000 | 500 | Standard highways constructed as described below. |
| Do | Private railway enterprises now in operation. | 6,000 | ..... | Railway — 3-foot gauge, 20-pound rail, 2,600 ties to mile. |
| Central Yukon: | | | | |
| Tanana, Birch Creek, and Koyukuk districts. | Estimate based on work done by Canadian government in Yukon Territory. | 1,200–3,000 | 350 | Standard highways constructed as described below. |
| Do | .....do ..... | 300 | 25 | Sled or winter trails. |

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## SOUTH COAST PROVINCE.

Wagon roads, while extremely useful in this portion of Alaska, cost so much that it is not likely they will be built except as heretofore, by private enterprise, to accommodate individual mining properties or groups of mines. The province is likely to prove in the future, as it has proved in the past, more important from the standpoint of quartz mining than of alluvial mining. The construction of roads is none the less desirable on this account, and should any large area capable of producing mineral be found at a point remote from the coast, a highway to it over which freight could be handled all the year round would be highly desirable. Winter conditions are exceedingly severe in the higher mountains. In the construction of the White Pass and Yukon Railway, 110½ miles in length, 1,500 men were employed for twenty-six months. Train service is maintained throughout the winter under considerable difficulty, both heavy winds and heavily drifted snow being frequently encountered. Rotary snow plows have to be run daily, encountering drifts from 15 to 35 feet in depth. The average cost of handling snow for a season is $75,000. Characteristic South Coast province topography is illustrated by Pl. XVI, *A*, p. 114.

## ATLIN DISTRICT AND YUKON TERRITORY.

In the Atlin district of British Columbia, which was visited during the present investigation, the topography is comparatively favorable to road construction, and it will be noticed from the table that the cost is low. Pl. XXXVIII, *B*, p. 220, shows a characteristic view of an Atlin road.

The Yukon Territory of Canada offers the most instructive lesson in practical highway construction in the north, and affords a striking contrast in this respect to the adjacent American domain. The officers of the department of public works of the Yukon Territory, notably Mr. S. A. D. Bertrand, the superintendent, and Mr. W. Thibaudeau, the Territorial engineer, were kind enough to place at my disposal the data relative to the building and maintenance of the public roads. The following summary can not fail to be of interest in this connection:

The longest road in the Territory is from Dawson to White Pass, 342 miles. Its history dates from 1899.

Prior to 1899 all freight from Dawson was transported to the mining creeks by pack animals in summer, and sledded either with dogs or horses over the ice and snow in winter.

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The following table shows the wagon roads and sled roads constructed:

*Roads constructed from 1899 to 1903.*

| | 1899. | 1900. | 1901. | 1902. | 1903. | Total. |
|---|---|---|---|---|---|---|
| | *Miles.* | *Miles.* | *Miles.* | *Miles.* | *Miles.* | *Miles.* |
| Wagon roads | 45 | 32 | 63.00 | 85.81 | 26 | 251.81 |
| Sled roads | 160 | 10 | 80.25 | 372.00 | 4 | 626.25 |

*Amount expended from 1899 to 1903 in constructing and maintaining roads and bridges in Yukon Territory, Canada.*

| | |
|---|---|
| 1899 | $50,000.00 |
| 1900 | 205,609.72 |
| 1901 | 147,174.90 |
| 1902 | 228,543.88 |
| 1903 | 398,789.95 |
| Total | 1,030,118.45 |

Average cost of construction for wagon road was $1,500 to $3,300 per mile. Average cost of construction for sled or winter trail was $250 to $350 per mile. The cost of repair and maintenance of wagon roads was $350 per mile per annum. The cost of repair and maintenance of sled roads was $25 per mile per annum.

The following comparative statement shows transportation charges, per 100 pounds between Dawson and a few of the important mining centers in 1899, previous to the construction of the wagon roads, and in 1904. The improved condition means a direct benefit to the miners of at least 600 per cent on all supplies and machinery freighted by wagons over first-class roads:

*Transportation charges, per 100 pounds, from Dawson to important mining centers in Yukon Territory, Canada.*

| From Dawson to— | Distance. | 1899. | 1904. |
|---|---|---|---|
| | *Miles.* | | |
| Grand Forks | 12 | $7.00 | $1.00 |
| Gold Bottom | 20 | 8.00 | 1.50 |
| Caribou | 33 | 12.50 | 2.00 |
| Discovery Sulphur | 35 | 12.50 | 2.00 |
| Gold Run | 55 | 18.00 | 3.00 |

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The following is a statement of the localities served by wagon roads:

*Localities served by wagon roads, with mileage, in Yukon Territory, Canada.*

| | Miles. |
|---|---|
| Bonanza Creek | 18.00 |
| Lovett Gulch | 1.50 |
| Adams Gulch | 1.75 |
| Eldorado Creek | 7.65 |
| Calder Creek | 5.60 |
| Gold Hill | .50 |
| Quartz Creek | 5.00 |
| Indian River and Eureka Creek | 18.00 |
| Hunker Creek | 24.35 |
| Bear Creek | 3.00 |
| Last Chance Creek | 2.50 |
| Gold Bottom Creek | 5.40 |
| Dominion Creek | 16.25 |
| Sulphur Creek | 9.56 |
| West Dawson | .41 |
| Henderson Creek | 13.00 |
| Duncan Creek (Stewart River district) | 20.00 |
| Livingstons Creek (Big Salmon district) | 16.00 |
| Copper King mines (White Horse district) | 4.20 |
| Grafter copper mine | 5.44 |
| Ridge road and spurs to Grand Forks, Gold Bottom, Caribou; and Gold Run. | 73.70 |
| Total | 251.81 |

Following is a statement of the localities served by sled roads:

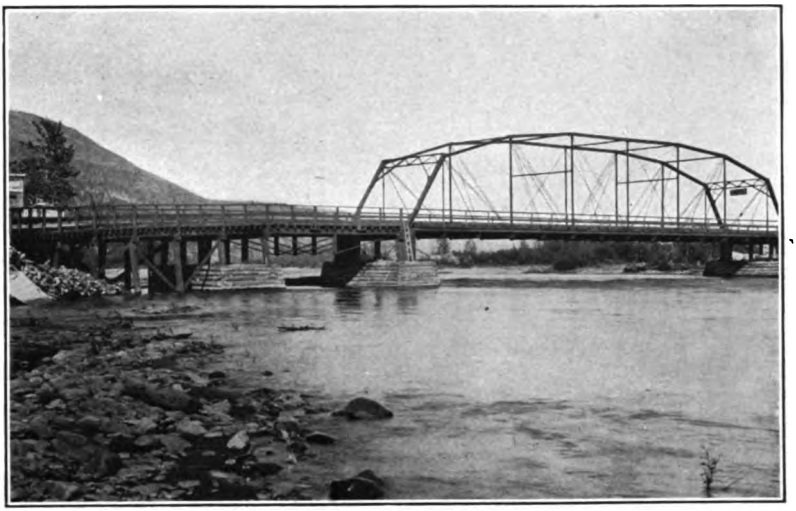
*Localities served by sled roads, with mileage, in Yukon Territory, Canada.*

| | Miles. |
|---|---|
| Old River cut-off from Lake Labarge to Hutchi, cut out in 1899 | 160.00 |
| Dawson-White Horse, overland mail route | 350.00 |
| Glacier-Miller Creek, Sixtymile district | 58.25 |
| Bucher Creek, Sixtymile district | 20.00 |
| Lepine Creek, quartz mines | 14.00 |
| Lower Sulphur | 8.00 |
| Last Chance (upper end) | 3.00 |
| Lower Dominion | 6.00 |
| Cut-offs, Stewart River | 20.00 |
| Duncan Creek (upper part) | 4.00 |
| Total | 643.25 |
| Less Eureka end of Dawson-White Horse trail (covered into wagon road) | 17.00 |
| | 626.25 |

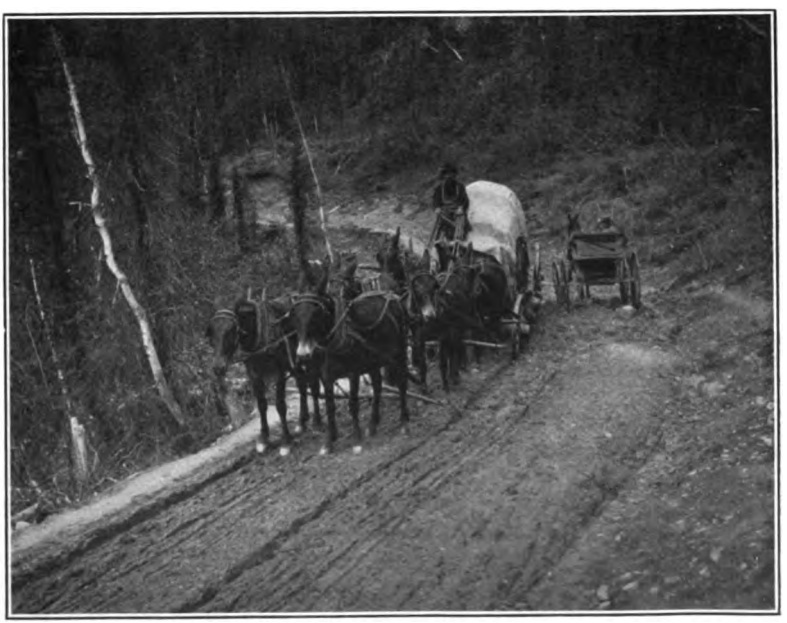
The estimate for the amount required for maintenance of roads and bridges in the Yukon Territory for the year ending June 30, 1904, is $103,190.

The men employed in road construction are paid $5 and board per day of ten hours. A team of horses, used in scraping or carting, is reckoned at $25 per day, including wages of the driver. Foremen are paid $6 and board per day of ten hours.

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*A*. OGILVIE BRIDGE, KLONDIKE RIVER.



*B*. SIX-MULE TEAM DRAWING 8,000 POUNDS, KLONDIKE.

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Several bridges of a permanent character have been built in the Territory, the principal of which is the Ogilvie steel bridge over Klondike River, the cost of which was $35,000. It is seen in Pl. XXXIX, *A*.

The method of constructing the road in the Yukon Territory, where frozen muck and gravel flats are traversed, is illustrated in fig. 49. This section was drawn from information furnished by Mr. W. Thibaudeau, Territorial engineer of the Yukon Territory. It has been the experience that over frozen ground this type of road, costing $3,200 per mile, can be maintained with much less expense than roads running along the hillsides. With roads of the kind here illustrated it has been found best to leave the moss intact under the bed of poles, for it protects the ground from thawing; the black frozen muck, having the consistency of solid stone, remains as a firm bed. The inside faces of the side ditches are not always banked with sod, but such banking affords additional protection. The ditches are cut either entirely

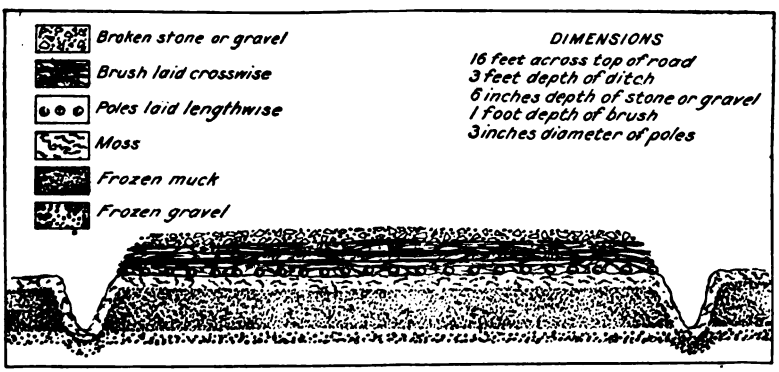



FIG. 49.—Method of constructing road over frozen muck, Klondike.

in muck or partly in muck and partly in underlying gravel. These conditions vary with the thickness of the muck.

On the other hand, when the moss blanket is cut into, as is necessarily the case in all side-hill cutting, the sun and the seepage water gradually thaw the frozen muck, which becomes a soft, slimy mass. The cost of maintenance of such roads has been found so much greater than that of roads on flat ground that the latter are now constructed, even if the distance between terminal points is greater.

Pl. XXXIX, *B*, shows a 6-mule team hauling 8,000 pounds with a trailer on an upgrade stretch of road in Hunker Creek, near Dawson. Pl. XL, *A* (p. 226), from a photograph taken in August, 1904, shows a 6-horse team endeavoring to haul a load of 3,300 pounds from Fairbanks, on Tanana River, to Cleary Creek, in the Fairbanks district of Alaska. Not half a mile from the point where this picture was taken, on the road to Cleary Creek, a cart bearing a 15-horsepower boiler was seen broken down, its wheels buried in mud and water.



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Two miles from the town of White Horse, Yukon Territory, on the road to the copper deposits, is an excellent stretch of corduroy road extending over a marshy piece of unfrozen ground. The 6-inch timbers used for lagging have all been flattened on the upper side for a width of 15 feet in the central portion, so that a rough wagon track is formed. Thus a much evener wear on the lagging is maintained than would be the case if the timbers were left in their original round condition.

## CENTRAL YUKON PROVINCE.

Mr. Alfred H. Brooks, in his article entitled "Placer Mining in Alaska in 1903,"[a] has suggested the following routes for Government roads in the central Yukon province of Alaska:

(1) A road from Eagle to the Tanana, the Chistochina, and to Valdez, on the coast, a distance of approximately 400 miles. This probably should follow the present well-established trail, which is used as winter and summer mail route. The most important part of the road would be that between Eagle and the camps of the Forty-mile region. An alternate route would be to Fairbanks, on the Tanana, from Copper River by way of the Delta River valley, a distance of about 300 miles. (2) A road to extend from Circle, on the Yukon, through the Birch Creek and Fairbanks district to the Tanana, a distance of about 150 miles. (3) Rampart, on the Yukon, to be connected with the mouth of Baker Creek, on the Tanana, by a road which would open up the Minook and Baker districts, a distance of less than 50 miles. (4) A hundred miles or so of road to be built in the Koyukuk region to connect the gold-bearing creeks with the head of steamboat navigation on Koyukuk River. It is believed that these roads would form a system of main arteries by which most of the placer fields could easily be reached, and that the production of the mines would thereby be so much increased as to fully justify the expense.

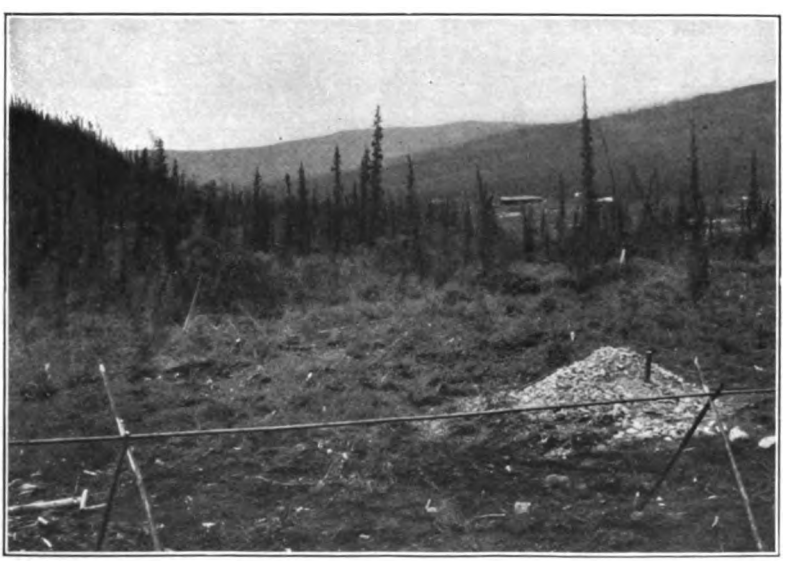
Well-constructed roads following the above routes would result in making freight rates in the placer districts which the roads would traverse one-fourth less than at present. The operations in the Birch Creek and New Fairbanks placer districts, for example, are directly dependent on prices of supplies laid down on the claims. The pay streaks in the broad creek valleys frequently become wider and wider as freight rates become lower. Such a statement would appear absurd if applied to regions where the charge for freighting represents only a small percentage of the original cost of the commodities. Where, however, the cost of material, especially machinery, is rendered double or more by freight charges, transportation facilities become a highly important factor in considering whether a given piece of ground is or is not workable. Prices for mining supplies in the town of Fairbanks, the supply point for the new gold-placer region on tributaries of Tanana River, are by no means cheap. As compared with prices on the claims which lie from 15 to 25 miles inland, however, they are

[a] Bull. U. S. Geol. Survey No. 225, 1904, p. 57.

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*A*. SIX-HORSE TEAM DRAWING 3,300 POUNDS, CLEARY CREEK, FAIRBANKS.



*B*. CREEK TOPOGRAPHY, FAIRBANKS DISTRICT.

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strikingly low. For example, a hundred feet of 8-inch 16-gage hydraulic riveted steel pipe costs in Fairbanks $175. On Fairbanks Creek, 20 miles away, the same 100 feet of pipe, with freight at 20 cents per pound, costs, if transported in summer, $301, representing a freight charge of $126. In the Klondike, where the topography is nearly the same, the same pipe would be landed on a claim 20 miles from Dawson for a freight charge of $9.45.

Anything worse than the present condition of the trails in the interior of Alaska is difficult to conceive. Men ignorant of the use of a map and compass are frequently lost in the vast maze of rolling mountains and undergo hardship and starvation. It is a curious fact, dependent on the peculiar frozen conditions, that the great river flats, where the present trails are at their worst, are the very places where wagon roads of the Dawson type can be most easily maintained. As for the hill country, the roads can, in many cases, be led almost continuously for distances of from 5 to 20 miles along the crests of gently rolling divides.

Pl. XL, *B*, shows one of the important producing creeks of central Alaska, where a road is badly needed, and Pl. XLI, *A*, illustrates the present mode of transportation in that district.

## SEWARD PENINSULA PROVINCE.

In the central and western portions of Seward Peninsula, namely, the Nome, Solomon, Council, Topkok, Kougarok, Teller, and York districts, any projects of installation of roads must take into account the entire absence of native timber. The region so defined is the one which has attained importance as a gold-producing area, while the eastern portion of the province, where scant growth of spruce does occur, is not at present productive. Pl. XLII illustrates typical Seward Peninsula topography.

Owing to these conditions wagon-road construction which employs the use of timber in any form will be expensive, and as seen by the table given previously in this paper, the cost of building the narrow-gage railways which have done excellent service in Seward Peninsula is $6,000 per mile, exclusive of rolling stock, while a wagon road of the Dawson type will rarely fall below $4,000 per mile. The rates for hauling on these railways may be reckoned at $1 per ton per mile. In summer, wagons with broad tires now haul freight over roads which have, as it were, made themselves, at rates of $1.50 to $3 per ton per mile, varying according to the nature of the country traversed.

It is questionable whether wagon roads, extensively built and aiming at permanency, will ever be constructed in Seward Peninsula to supply the needs of the gold-mining communities. The Nome

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Arctic Railway, from Nome to Anvil Creek, 12 miles long, the ties of which are laid for a portion of its length on a 2-inch plank bed, appears to serve a useful purpose. Only seventy days were consumed in the construction of the 12 miles. The Wild Goose Railway, also of 3-foot gage, from Council to Ophir Creek, has been constructed in a similar manner. Sixteen miles of a standard-gage railway, the Council City and Solomon River Railway, have also been completed. Considering the comparative cheapness with which railway material can be hauled at various points in Seward Peninsula, it is likely that short lines of railway will continue to be built by private enterprise to supply the several inland mining communities.

The suggestion is here made that narrow-gage pole tramways laid over the tundra might in some cases be used in parts of Seward Peninsula for long hauls. They would be expensive to construct and maintain, but would not, of course, compete with winter transportation.

In view of the small cost of narrow-gage railways in Seward Peninsula and the small annual maintenance cost, as compared with what it would probably cost to maintain wagon roads, the Federal Government should aid in tramway rather than wagon-road construction in that portion of Alaska. The light industrial railways now manufactured by various firms could be constructed with special modifications for the tundra country, and could be shipped, knocked down, to different portions of the peninsula.

In conclusion, I would say that of the three provinces of Alaska above specified, the central Yukon province is most in need of Federal aid for highway construction. By this means placer districts now lying idle could be made to support a numerous population, and it is doubtful whether any other form of assistance would prove as beneficial as stimulating prospecting for new placer fields.

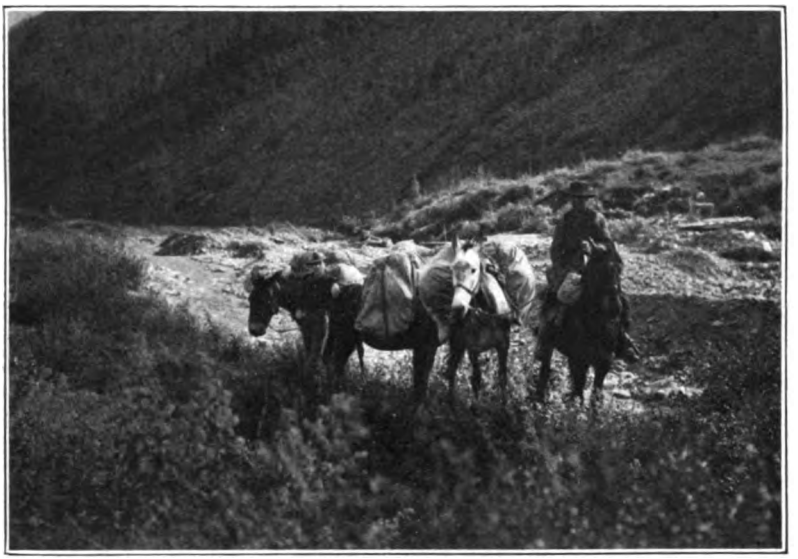
## FREIGHT RATES.

### FREIGHT RATES FROM THE STATES.

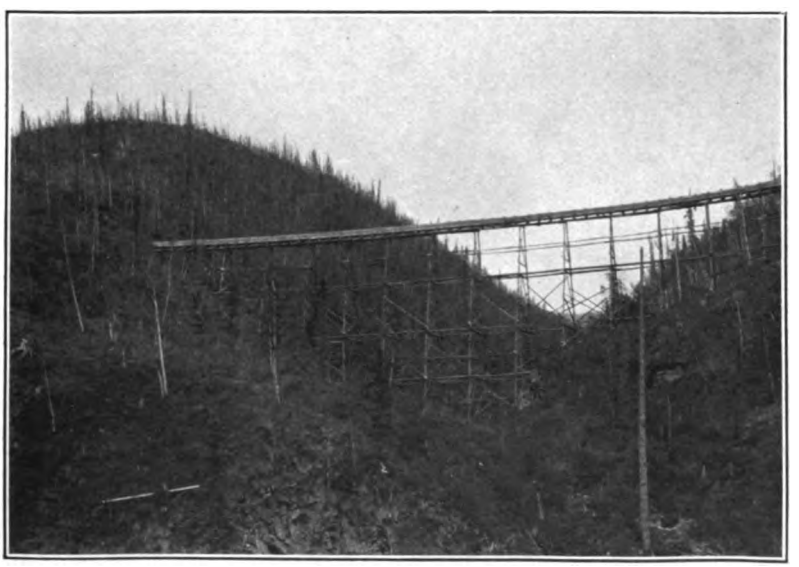
The present freight and passenger rates from Tacoma, Seattle, and San Francisco to the main supply points of Alaska accessible by ocean-going steamers are given in table 17 (pp. 230–231).

Freight rates are fairly constant from year to year, but passenger rates vary from one season to another, according as the different steamship companies are competing or temporarily combined. Return passenger rates may be reckoned at generally 25 per cent higher than north bound, but occasionally rise to 100 per cent higher. During 1904 the return rates from Nome were double those outgoing. It

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*A.* PACK TRAIN, BIRCH CREEK DISTRICT.



*B.* TRESTLED FLUME IN EAGLE DISTRICT.

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should be noted also that the return rates are higher on the last steamers than on those returning early in the season.

Service is maintained all the year round, with the exception of the Seward Peninsula service, St. Michael, and points far up Cook Inlet. Between these points and Seattle, service can be reckoned on from May 15 to October 15 only.

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TABLE 17.—*Ocean freight and passenger rates for 1904 from*

| | Loose machinery and iron articles in pieces weighing less than 2,000 pounds. | Machinery, single pieces weighing 2,000–4,000 pounds. | Machinery, single pieces weighing 4,000–6,000 pounds. | Machinery, single pieces weighing 6,000–8,000 pounds. | Machinery, single pieces weighing 8,000–10,000 pounds. | Machinery, single pieces over 10,000 pounds. |
|---|---|---|---|---|---|---|
| | *Per ton.* | *Per ton.* | *Per ton.* | *Per ton.* | *Per ton.* | |
| Wrangell | $9.00 | $11.00 | $14.00 | $18.00 | $22.00 | Special contract. |
| Juneau | 10.00 | 12.00 | 15.00 | 19.00 | 23.00 | ....do... |
| Skagway | 11.00 | 13.00 | 16.00 | 20.00 | 24.00 | ....do... |
| Yakutat | 13.00 | 15.00 | 18.00 | 22.00 | 26.00 | ....do... |
| Valdez | 11.00 | 13.00 | 16.00 | 20.00 | 24.00 | ....do... |
| Seward | 16.00 | 18.00 | 21.00 | 25.00 | 29.00 | ....do... |
| Hope and Sunrise | 19.50 | 21.50 | 24.50 | 28.50 | 32.50 | ....do... |
| Sand Point | 18.00 | 20.00 | 22.50 | 27.50 | 32.50 | ....do... |
| Service June 1–Oct. 1 only. St. Michael | 15.00 | 15.00 | 20.00 | 20.00 | 35.00 | $50 and higher. |
| Service June 1–Oct. 1 only. Cheenik | 15.00 | 15.00 | 20.00 | 25.00 | 35.00 | ....do... |
| Service June 1–Oct. 1 only. Solomon | 15.00 | 15.00 | 20.00 | 25.00 | 35.00 | ....do... |
| Service June 1–Oct. 1 only. Nome | 15.00 | 15.00 | 20.00 | 25.00 | 35.00 | ....do... |
| Service June 1–Oct. 1 only. Teller | 25.00 | 25.00 | 30.00 | 35.00 | 45.00 | $60 and higher. |
| Service June 1–Oct. 1 only. York | 25.00 | 25.00 | 30.00 | 35.00 | 45.00 | ....do... |
| Service June 1–Oct. 1 only. Bluff | 25.00 | 25.00 | 30.00 | 35.00 | 45.00 | ....do... |
| Kiwalik | 45.00 | 45.00 | | | | |

Coal is shipped from different points to Alaska, and the local price is given in tables for different Alaska towns.

Coal in sacks per ton, 2,240 pounds, Seattle to St. Michael or Nome, $12.

Freight and passenger rates from San Francisco to any of the above points do not exceed 5 per cent above Seattle rates.

The winter passenger trip between Seattle and Nome, via White Pass and Dawson, includes steamer, rail, horse-stage, and dog-sled travel, consumes three months, and costs about $1,000.

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*Seattle to Alaska coast points, including lightering when necessary.*

| General merchandise, including boxed machinery. | Boats and canoes. | Lumber. | Powder, dynamite and black. | Hay, double compress. | Grain. | Horses, mules, cattle. | Dogs. | Passengers. | | | Return freights. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | First-class. | Second-class. | Steerage. | Ore and concentrates not exceeding $100 per ton value. | | | Bullion and dust (per $1,000). |
| | | | | | | | | | | | 10 tons or under. | 10 to 110 tons. | 100 to 300 tons. | |
| *Per ton.* | | *Per M ft.* | *Per ton.* | *Per ton.* | *Per ton.* | *Per head.* | *Per head.* | | | | *Per ton.* | *Per ton.* | *Per ton.* | |
| $8.00 | $10.00–25.00 | $9.00 | $24.20 | $11.00 | $6.20 | $30.00 | $5.00 | $20.00 | $15.00 | ..... | $4.00 | $3.50 | $3.00 | $7.50–10.00 |
| 9.00 | 10.00–25.00 | 10.00 | 25.20 | 12.00 | 7.20 | 30.00 | 5.00 | 25.00 | 16.00 | ..... | 4.00 | 3.50 | 3.00 | 7.50–10.00 |
| 10.00 | 10.00–25.00 | 11.00 | 26.20 | 13.00 | 8.20 | 30.00 | 5.00 | 30.00 | 20.00 | ..... | 4.00 | 3.50 | 3.00 | 7.50–10.00 |
| 12.00 | 10.00–25.00 | 15.00 | 37.00 | 15.00 | 12.00 | 30.00 | 5.00 | 32.00 | 21.00 | ..... | 4.00 | 3.50 | 3.00 | 7.50–10.00 |
| 10.00 | 10.00–25.00 | 13.00 | 35.00 | 13.00 | 16.00 | 30.00 | 5.00 | 40.00 | 25.00 | ..... | 4.00 | 3.50 | 3.00 | 7.50–10.00 |
| 15.00 | 10.00–25.00 | 17.50 | 40.00 | 18.00 | 15.00 | 30.00 | 5.00 | 45.00 | 31.00 | ..... | 4.00 | 3.50 | 3.00 | 7.50–10.00 |
| 18.50 | 19.00–34.00 | 14.50 | 43.50 | 21.50 | 18.50 | 40.00 | 6.50 | 57.00 | 42.00 | ..... | ..... | ..... | ..... | 7.50–10.00 |
| 17.50 | 12.50–27.50 | 10.00 | 40.00 | 18.00 | 17.50 | 35.00 | 7.50 | 70.00 | 50.00 | ..... | 4.50 | 3.50 | 3.50 | 7.50–10.00 |
| | | 22.00 | | 20.00 | 18.00 | | | | | | | | | |
| 15.00 | Freight rates from Seattle or San Francisco vary from $10 to $15 per ton of 40 cubic feet. There is no classification. | | | | | 60.00 | ..... | 50.00–100.00 | ..... | $25.00–60.00 | $5.00 | | | 7.50–10.00 |
| 15.00 | | | | | | 60.00 | ..... | 50.00–100.00 | ..... | 25.00–60.00 | 5.00 | | | 7.50–10.00 |
| 15.00 | | | | | | 60.00 | ..... | 50.00–100.00 | ..... | 25.00–60.00 | 5.00 | | | 7.50–10.00 |
| 15.00 | | | | | | 60.00 | ..... | 50.00–100.00 | ..... | 25.00–60.00 | 5.00 | | | 7.50–10.00 |
| 25.00 | | | | | | 60.00 | ..... | 60.00–110.00 | ..... | 30.00–65.00 | 6.00 | | | 7.50–10.00 |
| 25.00 | | | | | | 70.00 | ..... | 70.00–120.00 | ..... | 35.00–70.00 | 6.00 | | | 7.50–10.00 |
| 25.00 | | | | | | 60.00 | ..... | 60.00–110.00 | ..... | 35.00–70.00 | 5.00 | | | 7.50–10.00 |
| 45.00 | | | | | | 85.00 | ..... | 80.00–130.00 | ..... | 55.00–90.00 | 10.00 | | | 7.50–10.00 |

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In table 18 are given the through freight and passenger rates from San Francisco or Seattle to Dawson, in Yukon Territory, and to Eagle, Circle, Fort Gibbon, and Fairbanks, in Alaska, via the White Pass route.

Table 19 gives the through rates from San Francisco or Seattle to the above-named points, via St. Michael and Yukon and Tanana rivers.

While during the open or summer season the all-water transport of freight via St. Michael is cheaper, the river steamboat service has not yet been developed to a sufficient extent to insure prompt and regular delivery. Should the Tanana gold fields prove important, however, the all-water route will probably be the one most practical for the transportation of supplies. It has the additional recommendation that by means of it the crossing and recrossing of the Canadian frontier is avoided. On the other hand, via the White Pass route, freight can be landed at Fairbanks much earlier than via the all-water St. Michael route.

It should be stated, in the consideration of table 18, that the White Pass and Yukon Railway has established three classifications of freight for through shipments, the regular rates for which, on less than 10 shipments from Seattle to Dawson for the summer season, are as follows:

Class A, including mining tools and articles bulky and not easily destructible, $65 per ton.

Class B, including more fragile articles, $80 per ton.

Class C, including small supplies, $95 per ton.

Shippers should remember that a package containing any article coming under a higher class than that comprising the bulk of the package is charged at the highest rate. This applies also to unspecified packages.

A list of mining supplies, on which a special reduction is made for transport from Seattle to Dawson between July 1 and August 15, is given following table 18.

The winter freight rates, via the White Pass route, exceeding $560 per ton from Seattle to Dawson need not be considered, as they are prohibitive, except in emergency cases. This route necessitates a haulage of nearly 300 miles by sleds.

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TABLE 18.—*Through freight and passenger rates for 1904 from Seattle to interior Yukon points, via White Pass route, rail and water—season June 15 to September 15.*

| Seattle to— | Loose machinery and tools in pieces less than 2,000 pounds.[a] | Machinery, single pieces weighing 2,000–4,000 pounds. | Machinery, single pieces weighing 4,000–6,000 pounds. | Machinery, single pieces weighing 6,000–8,000 pounds. | Machinery, single pieces weighing 8,000–10,000 pounds. | Machinery, single pieces weighing over 10,000 pounds. | General merchandise, including boxed machinery.[a] | Lumber, rough and flume.[a] | Powder, dynamite, and black. | Hay, double compressed.[a] | Grain.[a] | Horses and cattle. | Passengers.[b] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | First-class. | Second-class. |
| | *Per ton.* | *Per ton.* | *Per ton.* | *Per ton.* | *Per ton.* | *Per ton.* | | *Per M ft.* | | | | *Per head.* | | |
| Dawson | $65.00 | $65.00 | $80.00 | $80.00 | $95.00 | $100–150.00 | $80.00 | $97.00 | $120.00 | $65.00 | $65.00 | $80.00 | $80.00 | $65.00 |
| Fortymile | 75.00–80.00 | 83.00 | 100.00 | Special contract. | Special contract. | Special contract. | 90.00 | 112.00 | 135.00 | 75.00 | 75.00 | 90.00–95.00 | 87.00 | 70.00 |
| Eagle | 77.00–82.00 | 90.00 | 104.00 | ....do.... | ....do.... | ....do.... | 92.00 | 115.00 | 138.00 | 77.00 | 77.00 | 92.00–98.00 | 89.00 | 72.00 |
| Circle | 83.00–90.00 | 98.00 | 116.00 | ....do.... | ....do.... | ....do.... | 98.00 | 124.00 | 147.00 | 83.00 | 83.00 | 98.00–107.00 | 97.00 | 78.00 |
| Fort Yukon | 86.00–95.00 | 104.00 | 122.00 | ....do.... | ....do.... | ....do.... | 101.00 | 129.00 | 151.00 | 86.00 | 86.00 | 101.00–111.00 | 101.00 | 81.00 |
| Rampart | 91.00–102.00 | 111.00 | 132.00 | ....do.... | ....do.... | ....do.... | 106.00 | 136.00 | 159.00 | 91.00 | 91.00 | 106.00–119.00 | 111.00 | 88.00 |
| Fort Gibbon | 93.00–104.00 | 115.00 | 136.00 | ....do.... | ....do.... | ....do.... | 108.00 | 139.00 | 162.00 | 93.00 | 93.00 | 108.00–122.00 | 114.00 | 90.00 |
| Fairbanks | 135.00–163.00 | 191.00 | 220.00 | ....do.... | ....do.... | ....do.... | 150.00 | 202.00 | 225.00 | 135.00 | 135.00 | 150.00–185.00 | 150.00 | 115.00 |
| Koyukuk mouth | 99.00–113.00 | 126.00 | 149.00 | ....do.... | ....do.... | ....do.... | 114.00 | 148.00 | 171.00 | 99.00 | 99.00 | 114.00–131.00 | 124.00 | 98.00 |
| Nulato | 100.00–115.00 | 128.00 | 150.00 | ....do.... | ....do.... | ....do.... | 115.00 | 150.00 | 173.00 | 100.00 | 100.00 | 115.00–133.00 | 125.00 | 99.00 |
| Anvik | 104.00–120.00 | 136.00 | 158.00 | ....do.... | ....do.... | ....do.... | 119.00 | 156.00 | 179.00 | 104.00 | 104.00 | 119.00–139.00 | 134.00 | 106.00 |

[a] See special list following this table.
[b] The winter passenger rate from Seattle to Dawson per steamer, rail, and stage, is $150. From White Horse, Yukon Territory, is $100.

Beyond Dawson there is no regular winter transportation.
Winter rates for sledding on the Yukon are approximately:

| | Per ton. |
|---|---|
| Dawson to Eagle | $100.00 |
| Dawson to Circle | 240.00 |
| Eagle to Circle | 140.00 |

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The following rates from Seattle to Dawson, via the White Pass route, on commodities especially applicable to placer mining, are also given for summer traffic between July 1 and August 15:

*Freight rates from Seattle to Dawson, via White Pass route, from July 1 to August 15.*

| | | |
|---|---|---|
| Lumber, rough (including flume lumber or lumber dressed on one side only) | per M feet | $48.75 |
| Oats and feed, in straight or mixed carloads | per ton | 55.00 |
| Hay (compressed to at least 22 pounds per cubic foot) 7 tons or over | do | 52.50 |
| Blacksmith's coal, 20,000 pounds and over | do | 47.50 |
| Coal oil, 20,000 pounds and over | do | 47.50 |
| Candles, 20,000 pounds and over | do | 55.00 |
| Nails, horseshoes, bolts, nuts, and spikes, 20,000 pounds and over | do | 47.50 |
| Flour, 20,000 pounds and over | do | 52.00 |
| Beef in barrels | do | 62.50 |
| Iron and iron articles: Angle, band, bar, boiler, rod, hoop, sheet and galvanized iron, sheet steel, T rails, wire rope, bolts, anvils, nuts, nails, chains, per ton | | 52.00 |
| Hardware supplies: Asbestos cement, asphaltum, axle grease, bags and bagging, cement, clay (fire), handles, oil (lubricating in cases), pulleys, iron pumps (hand), rope and cordage, tar, tin plate, varnish, wheelbarrows, per ton | | 55.00 |

TABLE 19.—*Through freight and passenger tariff for 1904, between San Francisco, Seattle, and Yukon, Koyukuk, and Tanana River points, via St. Michael.*

| | North bound. | | | South bound. | | |
|---|---|---|---|---|---|---|
| | Passengers. | | Freight per ton of 2,000 pounds, or 40 cubic feet, ship's option. | Passengers. | | Freight per ton of 2,000 pounds, or 40 cubic feet, ship's option. |
| | First class. | Second class. | | First class. | Second class. | |
| Anvik | $103.00 | $70.00 | $40.00 | $97.00 | $66.00 | $35.00 |
| Nulato | 112.50 | 80.00 | 50.00 | 105.00 | 70.00 | 40.00 |
| Koyukuk mouth | 112.50 | 80.00 | 50.00 | 105.00 | 70.00 | 40.00 |
| Fort Gibbon | 125.00 | 88.00 | 55.00 | 112.50 | 75.00 | 45.00 |
| Fairbanks | 150.00 | 110.00 | 100.00 | 125.00 | 90.00 | 75.00 |
| Rampart | 127.50 | 90.00 | 57.00 | 115.00 | 77.50 | 48.00 |
| Fort Yukon | 135.00 | 95.00 | 62.00 | 120.00 | 85.00 | 53.00 |
| Circle | 135.00 | 95.00 | 65.00 | 120.00 | 85.00 | 55.00 |
| Eagle | 140.00 | 100.00 | 70.00 | 125.00 | 90.00 | 58.00 |
| Forty mile | 140.00 | 100.00 | 70.00 | 125.00 | 90.00 | 59.00 |
| Dawson | 140.00 | 100.00 | 70.00 | 125.00 | 90.00 | 60.00 |
| Bergman | 150.00 | ..... | 100.00 | 130.00 | ..... | 75.00 |
| Bettles | 165.00 | ..... | 135.00 | 140.00 | ..... | 95.00 |

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*Heavy pieces.*—On shipments to and from all river points, single pieces or packages weighing between 750 and 1,000 pounds, add 20 per cent; between 1,000 and 1,500 pounds, add 30 per cent; between 1,500 and 2,000 pounds, add 40 per cent; between 2,000 and 3,000 pounds, add 60 per cent; between 3,000 and 4,000 pounds, add 80 per cent; between 4,000 and 5,000 pounds, double rate; over 5,000 pounds taken only by special contract.

## LOCAL FREIGHT AND PASSENGER TARIFFS.

TABLE 20.—*Freight and passenger rates, for 1904, via river steamer from Dawson to points on Yukon and Tanana rivers. Return rates from 10 to 30 per cent higher.*

| Dawson to— | Freight per ton of 40 cubic feet or 2,000 pounds. | Passengers. | |
|---|---|---|---|
| | | First class. | Second class. |
| Fortymile, 53 miles | $10.00 | $7.00 | $5.00 |
| Eagle, 102 miles | 12.00 | 9.00 | 7.00 |
| Circle, 292 miles | 18.00 | 17.00 | 13.00 |
| Fort Yukon, 377 miles | 21.00 | 21.00 | 16.00 |
| Rampart, 620 miles | 26.00 | 31.00 | 23.00 |
| Fairbanks, 1,000 miles | 70.00 | 70.00 | 50.00 |
| Fort Gibbon, 700 miles | 28.00 | 34.00 | 25.00 |
| Nulato, 991 miles | 35.00 | 45.00 | 34.00 |
| Anvik, 1,196 miles | 39.00 | 54.00 | 41.00 |
| St. Michael, 1,601 miles | 48.00 | 70.00 | 50.00 |

Lumber, one and one-half the above rates per 1,000 feet B. M.

Horses and cattle, 1 to 5, one and one-half the above rates for each head; 6 to 10, one and one-quarter rate each head; over 10, one rate each head.

See footnote table 19 in regard to shipment of heavy pieces.

TABLE 21.—*Local passenger and freight tariff on Tanana River.*

PASSENGER TARIFF.

| Upstream. | | | | | | Downstream. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| From— / To— | Baker Creek. | Tolovana. | Neenana. | Chena. | Fairbanks. | From— / To— | Chena. | Neenana. | Tolovana. | Baker Creek. | Tanana. |
| Miles from Tanana... | 80 | 115 | 180 | 285 | 300 | Miles from Fairbanks | 15 | 120 | 185 | 220 | 300 |
| Tanana | $20 | $25 | $30 | $40 | $40 | Fairbanks | $5 | $15 | $20 | $25 | $25 |
| Baker Creek | .... | 10 | 20 | 30 | 35 | Chena | .... | 10 | 15 | 20 | 25 |
| Tolovana | .... | .... | 13 | 20 | 30 | Neenana | .... | .... | 10 | 15 | 20 |
| Neenana | .... | .... | .... | 20 | 25 | Tolovana | .... | .... | .... | 5 | 15 |
| Chena | .... | .... | .... | .... | 10 | Baker Creek | .... | .... | .... | .... | 10 |

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TABLE 21.—*Local passenger and freight tariff on Tanana River*—Continued.

FREIGHT TARIFF. [a]

| Upstream. | | | | | | Downstream. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| From— / To— | Baker Creek. | Tolovana. | Neenana. | Chena. | Fairbanks. | From— / To— | Chena. | Neenana. | Tolovana. | Baker Creek. | Tanana. |
| Miles from Tanana... | 80 | 115 | 180 | 285 | 300 | Miles from Fairbanks | 15 | 120 | 185 | 220 | 300 |
| Tanana | $20 | $25 | $35 | $45 | $45 | Fairbanks | $15 | $20 | $25 | $30 | $30 |
| Baker Creek | .... | 15 | 25 | 35 | 40 | Chena | .... | 15 | 20 | 25 | 30 |
| Tolovana | .... | .... | 20 | 30 | 35 | Neenana | .... | .... | 15 | 20 | 25 |
| Neenana | .... | .... | .... | 25 | 30 | Tolovana | .... | .... | .... | 15 | 20 |
| Chena | .... | .... | .... | .... | 20 | Baker Creek | .... | .... | .... | .... | 15 |

[a] Per ton of 2,000 pounds, or 40 cubic feet, ship's option.

TABLE 22.—*Local passenger tariff on Koyukuk River, season 1904.*

UPSTREAM.

| From— / To— | Koyukuk mouth. | Dagitli River. | Dulbi River. | Seattle Point. | Hog River. | Rock Island Point. | Red Mountain. | Bergman. | Allen River. | Peavy. | Bettles. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Miles from Nulato | 20 | 152 | 175 | 240 | 315 | 390 | 424 | 460 | 470 | 508 | 540 |
| Nulato | $5 | $16 | $18 | $24 | $34 | $44 | $48 | $51 | $54 | $60 | $66 |
| Koyukuk mouth | .... | 13 | 16 | 22 | 32 | 42 | 46 | 50 | 53 | 59 | 65 |
| Dagitli River | .... | .... | 5 | 11 | 21 | 31 | 35 | 40 | 43 | 49 | 54 |
| Dulbi River | .... | .... | .... | 8 | 18 | 28 | 32 | 37 | 40 | 46 | 52 |
| Seattle Point | .... | .... | .... | .... | 10 | 21 | 25 | 30 | 33 | 39 | 45 |
| Hog River | .... | .... | .... | .... | .... | 10 | 16 | 21 | 24 | 30 | 37 |
| Rock Island Point | .... | .... | .... | .... | .... | .... | 8 | 13 | 16 | 21 | 28 |
| Red Mountain | .... | .... | .... | .... | .... | .... | .... | 8 | 13 | 17 | 24 |
| Bergman | .... | .... | .... | .... | .... | .... | .... | .... | 5 | 15 | 20 |
| Allen River | .... | .... | .... | .... | .... | .... | .... | .... | .... | 10 | 15 |
| Peavy | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 10 |

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TABLE 22.—*Local passenger tariff on Koyukuk River, season 1904*—Continued.

DOWNSTREAM.

| From— / To— | Peavy. | Allen River. | Bergman. | Red Mountain. | Rock Island Point. | Hog River. | Seattle Point. | Dulbi River. | Dagitli River. | Koyukuk mouth. | Nulato. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Miles from Bettles | 32 | 70 | 80 | 116 | 150 | 225 | 300 | 365 | 388 | 520 | 540 |
| Bettles | $5 | $9 | $10 | $15 | $20 | $26 | $34 | $38 | $40 | $50 | $51 |
| Peavy | .... | 5 | 6 | 12 | 17 | 22 | 30 | 34 | 36 | 47 | 48 |
| Allen River | .... | .... | 3 | 8 | 13 | 18 | 26 | 30 | 32 | 43 | 44 |
| Bergman | .... | .... | .... | 5 | 9 | 14 | 22 | 26 | 29 | 40 | 41 |
| Red Mountain | .... | .... | .... | .... | 5 | 10 | 18 | 22 | 24 | 34 | 35 |
| Rock Island Point | .... | .... | .... | .... | .... | 8 | 14 | 18 | 20 | 30 | 31 |
| Hog River | .... | .... | .... | .... | .... | .... | 8 | 12 | 15 | 24 | 25 |
| Seattle Point | .... | .... | .... | .... | .... | .... | .... | 6 | 7 | 17 | 18 |
| Dulbi River | .... | .... | .... | .... | .... | .... | .... | .... | 4 | 14 | 15 |
| Dagitli River | .... | .... | .... | .... | .... | .... | .... | .... | .... | 11 | 12 |
| Koyukuk mouth | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 5 |

TABLE 23.—*Packing rates per 100 pounds from Rampart, Alaska, to various points in 1904.*

| | Distance. | Winter.[a] | Summer. |
|---|---|---|---|
| | *Miles.* | | |
| Hunter Creek | 4 | $2.00 | $4.00 |
| Little Minook Creek | 6 | 2.00 | 4.00 |
| Hoosier Creek | 8 | 2.00 | 4.00 |
| Ruby Creek | 10 | 2.00 | 6.00 |
| Slate Creek | 13 | 2.00 | 8.00 |
| Over divide to Pioneer Glen, Rhode Island, Omega, and Thanksgiving creeks | 25 to 32 | 6.00 | 15.00 |

[a] It should be said in regard to winter transportation that horses are gradually replacing dogs in all parts of Alaska. The dog is theoretically cheaper to feed than the horse. He gives more trouble, is more likely to give out on the trail, and experience has shown that in regions where horse feed can be obtained, and where much sledding is done, horses are cheaper.

*Circle–Fairbanks packing rates.*—The town of Circle, being the nearest point on Yukon River to the placer districts of Birch Creek and Fairbanks, has some importance, especially in winter, as a distributing center for those districts. The rates for packing in summer by horses and in winter by dog sleds from Circle are given in table 24.

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TABLE 24.—*Packing rates per 100 pounds from Circle to various points.*

| | Distance. | Winter. | Summer. |
|---|---|---|---|
| | *Miles.* | | |
| Deadwood Creek | 60 | $3.00 | $25.00 |
| Eagle Creek | 80 | 6.00 | 30.00 |
| Fairbanks Creek | 135 | 15.00 | 75.00 |
| Fairbanks | 150 | 35.00 | 100.00 |
| Fort Gibbon to Cleary Creek | ..... | 60.00 | ..... |

*Packing rates at Fairbanks.*—These summer rates are continually being reduced as the trails are improved, but the following may be regarded as those that will obtain in 1905:

TABLE 25.—*Packing rates per 100 pounds from Fairbanks to various points.*

| | Distance. | Winter. | Summer. |
|---|---|---|---|
| | *Miles.* | | |
| Pedro Creek | 15 | $2.00 | $10.00 |
| Chatham Creek | 20 | 2.50 | 10.00 |
| Cleary Creek | 22 | 2.50 | 15.00 |
| Upper Fairbanks Creek | 23 | 3.00 | 20.00 |
| Lower Fairbanks Creek | 25 | 3.00 | 25.00 |

In the summer of 1904 six-horse teams were engaged in hauling loads not exceeding 1½ tons from Fairbanks to the creeks. The conditions under which this hauling was done may be seen from Pl. XL.

The nearest American supply point to the creeks of the Fortymile region is Eagle, but this town, on account of its remoteness and the absence of good roads, is at present of only subordinate importance to the miners. Dawson, although in Canadian territory, is a more convenient place to procure supplies. These are bought generally in the fall and freighted to the creeks on sleds with dogs or horses during the winter, either by way of Sixtymile Creek or Fortymile Creek. In the summer freight is carried by pack train from Eagle or by boats from the Yukon up Fortymile Creek. The winter rates from Eagle in 1903 averaged about $5 per 100 pounds; the summer rates about $25.

Freighting to the new placer district of the Porcupine is done by wagon haul across Chilkat River to Portage Point, thence to Klukwan in canoes, which are poled upstream, sometimes under great difficulties. From Klukwan the supplies are hauled up the Klehini, 15 miles, to the town of Porcupine. The rate from Haines Mission to Porcupine is $3.50 per 100 pounds, and to Pleasant Camp, 6 miles beyond Porcupine, it is $5 per 100 pounds.

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Freight for the Chistochina district must be packed on horses from Valdez, via the military road to the Chistochina, and then up the river. The rate in 1903 was, in summer, $10 per 100 pounds, and in winter $3.50 per 100 pounds.

A railway has been projected from Resurrection Bay on the Alaska coast up the Sushitna and down the valley of Cantwell River to the Tanana, thence across to the Yukon at Rampart. A few miles of the road have actually been constructed from the Resurrection Bay terminus. There is little doubt that a railway following either this route or one following the already surveyed route from Valdez to Tanana Crossing would pay as an investment. The benefit of such lines of railway to the south interior portion of Alaska, including the Hope and Sunrise, Chistochina, and Fairbanks placer districts, is unquestionable.

Freight rates from Hope and Sunrise to the mining creeks in the vicinity are as follows:

Supplies are freighted from Sunrise to Mills Creek, about 18 miles, for 5 cents per pound.

From Sunrise to Lynx Creek, between 20 and 25 miles, for about the same. This is contract work.

Supplies are boated from Sunrise to mouth of Glacier Creek (7 to 8 miles) and there packed to Crow Creek (6 to 7 miles) for 3 to 3½ cents, but this is by private yearly contract. The miners usually bring their own supplies over the snow in the winter time so that there is not much freighting.

The transportation of supplies from supply points on Seward Peninsula to the mining creeks is done mainly by hauling in wagons; in some cases, as from Cheenik to Council, by flatboat, and in three cases, Nome–Anvil Creek, Solomon–East Fork, and Council Number 15, Ophir Creek, by railway. Between points on the coast the summer transportation depends on small ocean-going boats, for the most part gasoline launches, whose trips are not regular, as landings at Nome, Solomon, Bluff, and York depend on the weather. All supplies larger than those which can be transported in dories must be lightered at the above-named points. Charges for lightering at Nome are included in table 26. It should be understood that the ocean rates to Seward Peninsula points given in table 17 include the charge for lightering in every case.

The wagon haul is fairly easy at some times of the year in the broad, gravel-filled river beds. These streams are subject to flood, however, and such teaming is impossible at times. From White Mountain, on Fish River, to Council, Ophir Creek, Gold Bottom, and as far as Goose Creek, on the Casadepaga, a useful type of flatboat, drawn by a strong horse, draws 5 tons during favorable conditions of water. Such hauling, when possible, reduces the freight over the wagon haul by about 40

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per cent. Such horse boats can ascend the Casadepaga only during June and early July.

The freight rates from Teller to the creeks of the Kougarok district were not available in detail for this report. Freighting by wagon haul is, however, carried on from Teller, York, and some of the other more distant coast points of Seward Peninsula, and the rates may be figured as higher than at Nome in proportion to the increased cost of supplies at those coast points.

On Ophir Creek, in the Council district, it has been shown that the larger companies can reckon on obtaining their supplies direct from San Francisco via ocean steamer to Cheenik; flat steamers, Cheenik to mouth of the Niukluk; horse boat, Niukluk mouth to Council, and railway from Council to the creek, at a cost of approximately 2 cents a pound in excess of San Francisco prices. Table 26 gives the local freight rates from the main supply points to the creeks.

TABLE 26.—*Summer local freight and passenger rates from Nome to various points in Seward Peninsula, 1904.*

| Point. | Method of transportation. | General freight. | Lumber. | Horses and cattle. | Passengers. |
|---|---|---|---|---|---|
| | | *Per ton.* | *Per M ft.* | *Per head.* | |
| Solomon[a] | Steamer | $15.00 | $22.50 | $18.00 | $7.50 |
| Bluff[a] | do | 15.00 | 22.50 | 18.00 | 10.00 |
| Cheenik | do | 15.00 | 22.50 | 22.50 | 15.00 |
| Council | Steamer and flatboat. | 27.50 | 35.00 | 35.00 | 20.00 |
| Teller[b] | Steamer | 15.00 | 22.50 | 22.50 | 15.00 |
| York[a] | do | 20.00 | 30.00 | 30.00 | 20.00 |
| Kiwalik | do | 30.00 | 15.00 | 45.00 | 30.00 |
| Deering[a] | do | 30.00 | 45.00 | 45.00 | 30.00 |
| Anvil Creek | Wagon haul, railway.[c] | $10.00–15.00 | | | |
| Cooper Gulch | Wagon haul | 10.00 | | | |
| Moonlight Gulch | do | 10.00 | | | |
| Bourbon Creek | do | 10.00 | | | |
| Dry Creek | do | 5.00–10.00 | | | |
| Holyoke Creek | do | 10.00–15.00 | | | |
| Dexter Creek | do | 2.00 | | | |
| Buster Creek | do | 30.00 | | | |
| Lillian Creek | do | 30.00 | | | |
| Osborne Creek | do | 30.00–40.00 | | | |
| Seattle Creek | do | 37.50 | | | |
| Washington Creek | do | 30.00 | | | |
| Moss Gulch Creek | do | 30.00 | | | |

[a] No harbor. [b] Nome to Lanes landing via Kuzitrin River, $50 per ton. [c] Wagon haul, 1½-ton rates.

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TOPOGRAPHY, SEWARD PENINSULA PROVINCE.

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TABLE 26.—*Summer local freight and passenger rates from Nome to various points in Seward Peninsula, 1904*—Continued.

| Point. | Method of transportation. | General freight. | Lumber. | Horses and cattle. | Passengers. |
|---|---|---|---|---|---|
| | | *Per ton.* | *Per M ft.* | *Per head.* | |
| Peluk Creek | Wagon haul | $5.00–10.00 | | | |
| Otter Creek | do | 10.00–15.00 | | | |
| Martin Creek | do | 10.00–15.00 | | | |
| Glacier Creek | do | 30.00 | | | |
| Rock Creek | do | 30.00 | | | |
| Prospect Creek | do | 40.00 | | | |
| Lindbloom Creek | do | 40.00 | | | |
| Alpine Creek | do | 40.00 | | | |
| Sledge Creek | do | 40.00 | | | |
| Bolto Creek | do | 50.00 | | | |
| Bangor Creek | do | 60.00 | | | |
| Twin Mountain Creek | do | 60.00 | | | |
| Pioneer Creek | do | 60.00 | | | |
| Last Chance | do | 60.00 | | | |
| Penny River | do | 20.00–30.00 | | | |
| Willow Creek | do | 30.00 | | | |
| Oregon Creek | do | 100.00 | | | |
| Nugget Creek | do | 100.00 | | | |
| Cripple River | do | 40.00–50.00 | | | |
| Nome River, head | do | 100.00 | | | |
| Fountain Creek | do | 30.00 | | | |
| East Fork Solomon to Council. | Stage line | | | | $12.50 |

*Rates for lightering cargo at Nome.*

| | | |
|---|---|---|
| General merchandise, including small machinery | per ton | $5.00 |
| Machinery: | | |
| Two- to three-ton pieces | do | 7.50 |
| Three- to four-ton pieces | do | 10.00 |
| Four- to five-ton pieces | do | 15.00 |
| Five- to six-ton pieces | do | 20.00 |
| Six- to seven-ton pieces | do | 25.00 |
| Seven- to eight-ton pieces | do | 30.00 |
| Double-compressed hay | do | 5.00 |
| Coal in sacks | do | 3.50 |
| Coal put on beach and piled up | do | 4.00 |
| Lumber | per M feet | 5.50 |
| Live stock | per head | 6.00 |

Winter freighting, by means of horse and dog sleds, may be reckoned at about one-half the summer hauling rates.



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From Nome to Council, 85 miles, winter haul is—

| | |
|---|---|
| Warm-storage rate, per ton | $60.00 |
| Cold-storage rate, per ton | 40.00 |
| Passenger rate, forty hours | 15.00 |

*Summer local freight rates from Solomon to various points.*

| | Per ton. |
|---|---|
| Mouth Shovel Creek | $8.00–$12.00 |
| Hurrah Creek[a] | 10.00 |
| Willow Creek | 90.00 |
| Ruby Creek | 80.00 |
| Mystery Creek | 15.00 |
| West Creek | 12.50 |
| East Fork Creek | 15.00 |
| Down coast to Spruce Creek | 12.50 |

*Summer local freight rates from Council to various points.*

| | Per ton. |
|---|---|
| No. 15, Ophir Creek (railway) | $10.00 |
| Gold Bottom (horse boat) | 30.00 |
| Gold Bottom (wagon haul) | 50.00 |
| Lower Casadepaga | 75.00 |

## CUSTOMS REGULATIONS.

Considerable delay and confusion have been caused in the past by shippers not understanding the requirements of the United States and Dominion customs departments. The following information is given for the guidance of shippers, and the instructions herein contained must be strictly adhered to:

Shipments of goods from United States ports via Skagway, destined to Eagle City and other lower Yukon River points in transit through British Columbia and Yukon Territory, must be accompanied by 4 certified copies of invoices and 2 copies of bills of lading. All of these papers are necessary for customs purposes at Skagway.

Goods shipped from United States ports, destined to points in Alaska via Skagway and Yukon River, are bonded through Canadian territory duty free.

Charges for preparing customs papers by the customs agent of the White Pass and Yukon route will be as follows: For preparing shipper's manifest, 50 cents; transportation and exportation entries will be charged for on basis of actual cost to the White Pass and Yukon route.

The customs agent will notify the agent of the White Pass and Yukon route at Skagway station of the amounts to be assessed on above account, and the same will be placed against each shipment as a back charge.

[a] Under exceptionally favorable conditions large lots have been landed San Francisco–Little Hurrah Creek as low as $17 per ton.

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Difficulties of a peculiar nature are experienced by the placer miners of interior Alaska owing to the configuration of the international boundary between the Territory of Alaska and the British possessions. The town of Dawson, being the largest settlement of the interior, is naturally the point where mining supplies are most easily and quickly obtained by the placer miners of the neighboring American camps of Birch Creek and Fortymile, the Rampart district, and others of the Yukon and Tanana. During the season of 1904 the rapid and to a certain extent justifiable development of the town of Fairbanks, on Tanana River, gave promise that this settlement would eventually become as well equipped to supply the needs of the Tanana miners as is Dawson. The American Yukon camps must, however, for a considerable number of years be locally dependent on Dawson as a source of supplies.

Theoretically the miners are supposed to buy their mining supplies and machinery either at points in the United States or at towns on the Yukon in American territory. Such supplies, of course, if shipped down the Yukon, come through the Canadian territory in bond free of duty. In practice, however, owing to the necessity of obtaining supplies quickly, purchases are made in Dawson, and unless the supplies can be proved to be returned American goods the American miner must pay duties to the United States custom-house at Eagle according to the rates given in the following list. Frequently duties must be paid even on supplies made in the United States and returned, since there is no manufacturer's mark by which the customs inspector can identify them. This especially applies to such important mining supplies as small parts of boilers, tubes, pipe, pipe fittings, elbows, T's, unions, grate bars, sledges, drill steel, picks, shovels, pump plungers, buckets, valves, small car wheels, strap iron, rails, bar and rod iron, and small castings. Even larger pieces, such as parts of hydraulic giants, are frequently unstamped. These supplies, kept for sale by the machinery firms of Dawson, frequently pay customs duties both to Canada and the United States before reaching the Alaska camps. Dawson is frequently sought by the American miners in the midst of the short season for the purpose of repairs to various mining machinery, it being the only place accessible on the Yukon where machine shops exist. It may easily be seen how burdensome on the miner is the imposing of a duty on his machinery which he brings back into American territory after repairs, and on which he must pay a duty because it has been improved or changed in foreign territory.

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Below are given the United States customs duties on small mining supplies:

*United States customs duties.*

| Articles. | Duty. |
|---|---|
| Boilers and engines, first and second hand | 45 per cent ad valorem. |
| Points (steam), sluice forks, picks, shovels, axes | 45 per cent ad valorem. |
| Sledges | 1½ cents per pound. |
| Drill steel | 4.7 cents per pound. |
| Hydraulic hose | 20 cents per pound. |
| Cast pipe | 4.7 cents per pound. |
| Hydraulic pipe | 2 cents per pound. |
| Gas pipe | 35 per cent ad valorem. |
| Rubber hose | 30 per cent ad valorem. |
| Coke | 25 per cent ad valorem. |
| Bituminous coal | 67 cents per ton. |
| Dynamite | 6 cents per pound. |
| Black powder | 6 cents per pound. |
| Caps | $2.36 per thousand. |
| Fuse | 45 per cent ad valorem. |
| Candles | 25 per cent ad valorem. |
| Nails, wire | One-half cent per pound. |
| Nails, wrought iron | 2¼ cents per pound. |
| Steel rails | Seven-twentieths cent per pound. |
| Wire cable | 1 cent per pound and 40 per cent ad valorem. |
| Centrifugal pumps | 45 per cent ad valorem. |
| Sawed lumber | $2 per thousand and 50 cents for each side dressed. |
| Wheelbarrows, iron | 45 per cent ad valorem. |
| Rope | 1 cent per pound. |
| Self-dumping carriers | 45 per cent ad valorem. |
| Asphalt coating | $3 per ton. |
| Hydraulic giants | 45 per cent ad valorem. |
| Lubricating oils | 25 per cent ad valorem. |
| Copper plates | 2½ cents per pound. |
| Cement | 8 cents per 100 pounds. |
| Quicksilver | 7 cents per pound. |
| Iron castings | Eight-tenths cent per pound. |
| Iron castings, ground and fitted | 45 per cent ad valorem. |

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It should be stated that there is a duty on all horses, cattle, sheep, and dogs[a] entering Alaska. Thus a dog team coming down river from Dawson in the winter is dutiable.

During the season of 1904 a United States customs inspector accompanied the Yukon steamers from Dawson with shipments from that point to Fairbanks, in order to obviate the long delays which had previously been necessary for appraisement at Eagle.

Owing to the export duty on gold which is charged by the Canadian government, some difficulties have been experienced by Americans who bring gold mined in Alaska Territory through Canadian territory, via Dawson, en route to the United States. The Canadian government naturally assumes that all gold found on south-bound passengers leaving Canadian territory at White Pass has been mined in Canada. Such gold is therefore liable to confiscation by the officers in charge of collection of royalty unless the bearer is provided with a properly ratified certificate stating that the gold is of foreign production. American miners should obtain such a certificate at Eagle from the United States authorities (fee, 10 cents) and have the same ratified at Dawson by the Canadian police (fee, 50 cents for gold from 1 to 25 ounces, $1 for 25 ounces and upward). All individuals leaving Yukon Territory for United States territory are strictly searched for gold.

The regulations in regard to boats coming down the Yukon into United States territory must also be taken into consideration. No boat or scow, not a regular carrier, can, for example, make the journey from Dawson to Circle, carrying over 5 tons of freight. This is especially burdensome on settlers who wish to outfit at Dawson and float their goods down the Yukon. The situation, owing to the conditions, is undoubtedly a burden of extra expense on the miner, but is unavoidable, and must be reckoned with in any estimate of expenses attending the prosecution of placer mining in the Alaska interior.

## TELEGRAPH RATES.

By means of the United States military telegraph line in Alaska, including the wireless system from St. Michael to Port Safety and the Seattle-Sitka-Valdez cable with connection to Juneau and Skagway, an all-American service is now maintained from all important points of Alaska (except Circle) to the outside world.

The rates for the military service in Alaska are based upon a tariff of 2 cents per word for each 100 miles or fraction thereof, address and signature not counted, a message of less than 10 words being charged for as a 10-word message. During the month of September, 1904, a

[a] Horses, value $150 or less, $30 per head; over $150, 25 per cent ad valorem. Dogs, 20 per cent ad valorem; cattle, $2 per head, under 1 year old; others, 27½ per cent ad valorem.

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cable line was completed between Sitka and Valdez, which, with the Sitka–Seattle cable, completes the American telegraph service to all parts of Alaska. Through 10-word rates from Seattle are as follows:

*Telegraph rates from Seattle to points in Alaska.*

| | |
|---|---|
| Sitka | $2.50 |
| Juneau | 2.75 |
| Skagway | 3.00 |
| Valdez | 3.50 |
| Nome | 4.00 |
| Eagle | [a]3.00 |
| Rampart | [a]3.50 |
| Fairbanks | [a]3.50 |

## DISTANCES AND COST OF SUPPLIES.

Tables Nos. 27, 28, and 29 give approximate distances in Alaska.

TABLE 27.—*Distances, in miles, between towns in Alaska, excluding Seward Peninsula.*

| | Juneau. | Valdez. | Haines. | St. Michael. | Nulato. | Fort Yukon. | Rampart. | Fort Gibbon. | Fairbanks. | Circle. | Eagle. | Fortymile. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Valdez | 580 | | | | | | | | | | | |
| Haines | 100 | 600 | | | | | | | | | | |
| St. Michael | 1,880 | 1,300 | 1,900 | | | | | | | | | |
| Nulato | 1,140 | 1,720 | 1,249 | 485 | | | | | | | | |
| Fort Yukon | 963 | 1,543 | 864 | 990 | 505 | | | | | | | |
| Rampart | 208 | 1,783 | 984 | 750 | 265 | 240 | | | | | | |
| Fort Gibbon | 1,268 | 1,848 | 1,049 | 685 | 200 | 305 | 65 | | | | | |
| Fairbanks | 1,423 | 2,003 | 1,204 / [b]920 | 840 | 355 | 455 | 220 | 155 | | | | |
| Circle | 878 | 1,458 | 779 | 1,075 | 590 | 85 | 325 | 270 | [c]150 | | | |
| Eagle | 745 | 1,325 | 646 | 1,208 | 723 | 218 | 458 | 523 | [c]283 | 135 | | |
| Fortymile | 695 | 1,275 | 596 | 1,253 | 768 | 263 | 503 | 568 | 328 | 180 | 45 | |
| Dawson | 647 | 1,227 | 548 | 1,298 | 813 | 308 | 548 | 613 | 373 | 225 | 90 | 45 |

[a]35 cents each additional word. [b]Taking trail at Circle. [c]By trail.

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TABLE 28.—*Distances, in miles, between points on Seward Peninsula.*

| | Nome. | Cheenik. | Council. | Bluff. | Solomon. | Teller. | York. | Kewalik. | Blossom. |
|---|---|---|---|---|---|---|---|---|---|
| Cheenik | 90 | | | | | | | | |
| Council | 135 | 45 | | | | | | | |
| Bluff | 65 | 25 | 70 | | | | | | |
| Solomon | 34 | 56 | 101 | 31 | | | | | |
| Teller | 100 | 190 | 235 | 165 | 134 | | | | |
| York | 110 | 200 | 245 | 175 | 144 | 45 | | | |
| Kiwalik | 345 | 435 | 480 | 410 | 379 | 280 | 235 | | |
| Blossom | 310 | 400 | 445 | 375 | 344 | 245 | 200 | 55 | |
| Candle | 360 | 450 | 495 | 425 | 394 | 295 | 250 | 7 | 62 |

TABLE 29.—*Distances from main supply points in Alaska to neighboring creeks.*

FROM CIRCLE.

| | Miles. |
|---|---|
| Diggings on Deadwood Creek | 40 |
| Mouth of Boulder Creek | 35 |
| Junction of Mastodon and Independence creeks | 47 |
| Mouth of Miller Creek | 45 |
| Junction of Mastodon Fork and Eagle Creek | 53½ |

FROM FAIRBANKS.

| | |
|---|---|
| Gilmore at crossing of trail | 14 |
| Junction of Twin and Pedro creeks | 18 |
| Junction of Wolf and Cleary creeks | 24 |
| Fairbanks Creek at mouth of Alder Gulch | 27 |

FROM NOME.

| | |
|---|---|
| Discovery on Anvil Creek | 4 |
| No. 3 above on Glacier Creek | 7½ |
| Junction of Grass Gulch and Dexter Creek | 7 |
| Cooper Gulch | 4 |
| Bourbon Creek (passes through Nome). | |
| Holyoke Creek | 2½ |
| Dexter Creek | 7 |
| Buster Creek | 9 |
| Lillian Creek | 11 |
| Osborne Creek | 7 |
| Seattle Creek | 22 |
| Washington Creek | 6 |
| Moss Gulch | 6½ |
| Peluk Creek | 2 |
| Otter Creek | 3½ |
| Martin Creek | 2½ |
| Rock Creek | 3½ |
| Prospect Creek | 12 |
| Lindebloom Creek | 11 |
| Alpha Creek | 11½ |

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| | Miles. |
|---|---|
| Sledge Creek | 13 |
| Balto Creek | 12½ |
| Bangor Creek | 17 |
| Twin Mountain Creek | 15 |
| Last Chance Creek | 20 |
| Penny River | 11 |
| Willow Creek | 10 |
| Oregon Creek | 19 |
| Nugget Creek | 18 |

FROM SOLOMON.

| | |
|---|---|
| Mouth of Shovel Creek | 5 |
| Mouth of Kasson Creek | 10 |
| Mouth of Big Hurrah Creek | 8½ |
| Mouth of East Fork | 11 |
| Mouth of Coal Creek | 15 |
| Head of Ruby Creek (Casadepaga drainage) | 20 |
| Head of Penelope Creek (Casadepaga drainage) | 21 |
| Mouth of Goose Creek (Casadepaga drainage) | 25 |

FROM COUNCIL.

| | |
|---|---|
| Mouth of Ophir Creek | 2½ |
| Mouth of Dutch Creek | 8 |
| Mouth of Crooked Creek | 11 |
| Mouth of Basin Creek | 2 |
| Junction of Gold Bottom and Warm Creek | 8 |
| Mouth of Mystery Creek | 4 |

FROM TELLER.

| | |
|---|---|
| Bering Creek | 13 |
| Mouth of Right Fork of Bluestone River | 15 |
| Mouth of Alder Creek | 17 |
| Mouth of Ruby Creek | 13 |
| Mouth of Sunset Creek | 3½ |
| Marys Igloo | 50 |

FROM MARYS IGLOO.

| | |
|---|---|
| Quartz Creek | 24 |
| Angeles Creek | 33 |
| Goodall Creek | 43 |
| Homestake Creek | 52 |
| Macklin Creek | 56 |
| North Fork of Kougarok River | 21 |
| Harris Creek | 20 |
| Mouth of Baldy Creek | 20 |
| Mouth of Portage Creek | 22 |

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TABLE 30.—*Prices of mining supplies in the North.*

| | Juneau. | Dawson.[a] | Circle. | Mastodon post-office, Birch Creek region. | | Fairbanks. | Nome. |
|---|---|---|---|---|---|---|---|
| | | | | Summer. | Winter. | | |
| Asphalt coating | 8 cts. per gal. | $2 per gal. | | | | | 75 cts per gal. |
| Boilers: | | | | | | | |
| 50-horsepower return-flue, American manufacture. | | $1,800 | | | | $3,000[b] | |
| 40-horsepower return-flue | | $1,600 | | | | $2,500 | |
| 25-horsepower return-flue | | $1,200 | | | | $1,800 | (c) |
| 10-horsepower return-flue | | $600 | | | | $1,100 | |
| 5-horsepower return-flue | | $300 | | | | $500 | |
| Caps | 98 cts. per 100 | $1.50 per 100 | | | | $1.75 per 100 | $1.50 per box. |
| Candles | $2.40 per box | $3.75 per box | $4 per box | $6 per box | $4.50 per box | $4 per box | $2.50 per box. |
| Cars, self-dumping, ore | | $45 | | | | $50 | |
| Cement | $4.25 per bbl | $20 per bbl | | | | $25 per bbl | $9 per bbl. |
| Clay (fire) | | 10 cts. per lb. | | | | 15 cts. per lb. | 15 cts. per lb. |
| Copper plates | $2 per sq. ft. | 50 cts. per lb. | | | | 75 cts. per lb. | $1 per sq. ft. |
| Copper wire | 40 cts. per lb. | 60 cts. per lb. | | | | 75 cts. per lb. | 50 cts. per lb. |
| Coal, blacksmith | $22 per ton | $100 per ton | $140 per ton | $25 per cwt | $10 per cwt | $120 per ton | $35 per ton.[d] |
| Coal, fuel, local mine | | $12 to $16 per ton | | | | | |
| Coke | $30 per ton | 5¼ cts. per lb. | | | | 6 cts. per lb. | |
| Coal oil | $2.90 per case | 50 cts. per gal. | $9 per case. | $15 per case. | $10 per case. | 75 cts. per gal | $3.50 per case 10 gal.[e] |
| Drilling steel | 12 cts. per lb. | 20 cts. per lb. | 15 to 25 cts. per lb. | 25 to 35 cts | 20 to 30 cts | 20 cts. per lb. | 25 cts. per lb.[f] |

[a] Prices at Eagle are practically the same as at Dawson, plus duty on imported supplies.

[b] Includes duty in coming from Dawson, Yukon Territory; can be landed from outside to Fairbanks a little cheaper than at Dawson; portable return tubular made in Erie, Pa., or in Oil City, considered most economical for this class of work; Scotch marine type is best for dirty water used in this work, but is much heavier; 40-horsepower weighs 12,100 pounds, and about 1 ton heavier for each additional 10-horsepower; 50-horsepower weighs 11,700 pounds; 40-horsepower weighs 10,400 pounds; 25-horsepower weighs 7,300 pounds; 10-horsepower weighs 4,300 pounds; 5-horsepower weighs 1,300 pounds.

[c] Second-hand boilers, 6-horsepower, $200; 8-horsepower, $200; 10 to 15-horsepower, $250 to $300; 20-horsepower, approximately, $500; 25 to 30-horsepower, $600 to $750; 50-horsepower, $1,000.

[d] Bituminous coal, $17.25 a ton; anthracite, about $40 a ton.

[e] $4 a barrel of 42 gallons. Pearl is $3.25 a case of 10 gallons.

[f] Soft steel, 10 cents a pound; also soft iron, 10 cents a pound.

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TABLE 30.—*Prices of mining supplies in the North*—Continued.

| | Juneau. | Dawson. | Circle. | Mastodon post-office, Birch Creek region. | | Fairbanks. | Nome. |
|---|---|---|---|---|---|---|---|
| | | | | Summer. | Winter. | | |
| Engines: | | | | | | | |
| 40-horsepower | | $1,000 | | | | $2,000 | |
| 25-horsepower | | $650 | | | | $1,500 | (a) |
| 16-horsepower | | $500 | | | | $1,000 | |
| 8-horsepower | | $300 | | | | $600 | |
| Fittings (steam-pipe) | | 20 cts. per lb | | | | 40 cts. per lb | (b) |
| Fuse | 65 cts. per 100 feet. | $1 per 100 feet | $1.50 per 100 ft | | | $2 per 100 ft | $1 per 100 ft. |
| Gasoline (distillate) | $3.75 per case | $9 per 10-gal | $9 to $10 per case | | | $15 per 10-gal. case | $3.50 to $4 per case. |
| Handles (pick and sledge) | $3 to $3.35 per doz. | $6 per doz | $7.50 to $9 per doz. | $1 each | | $12 per doz | $6 per doz. |
| Hoists, steam: | | | | | | | |
| 8-horsepower single-cylinder vertical. | | | | | | $550 | |
| 15-horsepower double-drum and engine. | | $1,200 | | | | $2,500 c | (a) |
| 12-horsepower double-drum and engine. | | $800 | | | | $2,000 | |
| Hulls, barge at St. Michael d | | | | | | | |
| Hose, steam: | | | | | | | |
| ¼-inch 6-ply | 46 cts. per ft | 60 cts. per ft | | | | 75 cts. per ft | 60 cts. per ft. |
| ½-inch 6-ply | 60 cts. per ft | 75 cts. per ft | | | | $1 per ft | 75 cts. per ft. |
| Hose, hydraulic, 12 ounces: | | | | | | | |
| 6-ply (imported) | | $1.25 per ft | | 55 cts. e | | $1.50 per ft | 35 cts. per ft. |
| 8-ply (imported) | | $1.50 per ft | | | | $1.75 per ft | 50 cts. per ft. |
| Hose, fire 2½-ply | | $1.50 per ft | | | | $1.50 per ft | |
| Hydraulic pipe: | | | | | | | |
| 6-inch f | | $1.25 per ft | | | | $1.50 per ft | |
| 8-inch | | $1.50 per ft | | | | $1.75 per ft | |
| K. D., 6-inch | | 90 cts. per ft | | | | $1 per ft | |
| K. D., 8-inch | | $1 per ft | | | | $1.25 per ft | |

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Hydraulic giants: | | | | | | | |
| No. 0 | | $75 | | | | $100 | |
| No. 2 | | $150 | | | | $175 | |
| Iron: | | | | | | | |
| Sheet | 4 cts. per lb | 12 cts. per lb | 15 cts. per lb | 25 cts. per lb | 18 cts. per lb | | 8 cts. per lb. |
| Corrugated | | $9 per sq | 15 cts. per lb | | | $10 per sq | 7 cts. per lb. |
| Bar, galvanized | 5 cts. per lb | 10 cts. per lb | 15 cts. per lb | | | 15 cts. per lb | |
| Lumber: | | | | | | | |
| Rough | $12 per M | $50 per M | | $110 per M | | $75 per M | $32.50. per M. |
| Planed | $13 per M | $70 per M | | | | $100 per M | |
| Small stripping | | 2 cts. per lin. ft | | | | 3 cts. per lin. ft | |
| Nails, wire | $3 per keg | $8 per keg | $12.50 per cwt | 25 cts. per lb | 18 cts. per lb | $10 per keg | $6 per keg. |
| Oil, lubricating: | | | | | | | |
| Cylinder | 85 to 90 cts. per gal. | $1.75 per gal | 75 cts. per gal | | | $2 per gal | $1 per gal. |
| Machine | 35 to 40 cts. per gal. | $1.50 per gal | 50 cts. per gal | $1 per gal | | $1.50 per gal | 75 cts. per gal. |
| Petroleum, crude, $1.70 barrel; 4 barrels ton; St. Michael. | | | | | | | |
| Pans, gold | 20 cts. each | 75 cts. each | $1 each | $1.50 each | | $1 each | 50 cts. each. |
| Pipe, cast-iron: | | | | | | | |
| ¼-inch | 4½ cts. per ft | 12 cts. per ft | | | | 20 cts. per ft | |
| ¾-inch | 5½ cts. per ft | 15 cts. per ft | | | | 25 cts. per ft | |
| 1-inch | 7 cts. per ft | 20 cts. per ft | | | | 30 cts. per ft | |
| Picks, without handles | $7 per doz | $22 per doz | $20 to $24 per doz | | | $25 per doz | $12 per doz. |
| Pumps: | | | | | | | |
| Force— | | | | | | | |
| 2-inch | | $175 | | | | $300 *g* | |
| 3-inch | | $350 | | | | $400 | |

*a* 25-horsepower double drum, hard to get, $1,250; 8 to 10-horsepower, $350 to $600.
*b* Small fittings same as Seattle; ¾-inch pipe, 10 cents a foot; 1-inch, 12½ cents; 1¼-inch, 15 cents; 1½-inch, 20 cents; 2-inch, 25 cents; 6-inch, $1 a foot.
*c* Made in San Francisco for self-dumpers, 50-pan steel bucket. A 6-horsepower weighs 1,000 pounds, costs $450 for a 30-pan bucket; is also obtainable at Fairbanks; 15-horsepower weighs 5,500 pounds; 12-horsepower weighs 3,200 pounds.
*d* Barge, 100 by 26 feet by 6 feet 6 inches, Oregon fir, good for 200 tons at 4 feet draft, costs between $4,000 and $5,000; cost to tow to Dawson, $1,500; to Fairbanks, $1,250.
*e* Manufactured in Dawson, 15 ounces, 9 to 14 inches diameter, for 15 to 30 cents a foot.
*f* See prices of hydraulic machinery in San Francisco, under "Hydraulic mining."
*g* 750 pounds and 1,050 pounds.

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TABLE 30.—*Prices of mining supplies in the North*—Continued.

| | Juneau. | Dawson. | Circle. | Mastodon post-office, Birch Creek region. | | Fairbanks. | Nome. |
|---|---|---|---|---|---|---|---|
| | | | | Summer. | Winter. | | |
| **Pumps—Continued.** | | | | | | | |
| Centrifugal— | | | | | | | |
| 5-inch | | $200 | | | | $250[a] | |
| 6-inch | | $250 | | | | $800 | |
| 10-inch | | $500 | | | | $800 | |
| 8-inch | | | | | | $650 | |
| **Powder:** | | | | | | | |
| Dynamite | 60 per cent, 18 cts. per lb. | 35 cts. per lb | | | | 50 cts. per lb | |
| Black | | $2.75 per keg of 25 lbs. | 75 cts. to $1 per lb. | | | $3 per keg of 25 lbs | |
| Quicksilver | 65 cts. per lb | $1 per lb | $1 per lb | | | $1 per lb | |
| Rockers (frame built in Dawson) | | $2.75, plates | | | | $3 | |
| **Rope:** | | | | | | | |
| Manila | 13 cts. per lb | 30 cts. per lb | $30 to $35 per cwt. | | | 40 cts. per lb | |
| Wire— | | | | | | | |
| ⅜-inch | | 16 cts. per ft | | | | 18 cts. per ft | |
| ½-inch | | 18 cts. per ft | | | | 22 cts. per ft | |
| ⅝-inch | | 22½ cts. per ft | | | | 24 cts. per ft | |
| ¾-inch | | 30 cts. per ft | | | | 32 cts. per ft | |
| Shafting | 44 cts. per lb | 15 cts. per lb | | | | 20 cts. per lb | |
| Shovels | $8.50 per doz | $18 per doz | $20 to $24 per doz. | $3 each | $2.50 each | $20 per doz | $9 per doz. |
| Sluice forks | $1.35 each | $20 per doz | $3.50 each | $5 each | $3.50 each | $25 per doz | $18 per doz. |
| Steel plates and bars | 9 to 20 cts. per lb. | 12 cts. per lb | 15 cts. per lb. | | | 15 cts. per lb | 12 cts. per lb. |
| Steel rails, T, 8-pound | | 10 cts. per lb | | | | 15 cts. per lb | 6 cts. per lb. |
| Thawing points, one-half and three-fourth inch steel head. | | $10 each | $8 to $10 each | | | $10 each | $5.50 each. |
| Wheels for cars | | $17.50 per set | | | | $20 per set | $20 per set. |

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Bolts | | | 15 cts. per lb. | 20 cts. per lb. | 18 cts. per lb. | 25 cts. per lb. | |
| Nuts | 6 cts. per lb. | 20 cts. per lb. | 15 cts. per lb. | 20 cts. per lb. | 18 cts. per lb. | 25 cts. per lb. | 15 cts. per lb. |
| Spikes | | 10 cts. per lb. | | | | 15 cts. per lb. | $6 per keg. |
| Scrapers: | | | | | | | |
| No. 1 | | $22.50 each. | $10 to $20 each. | $35 each | $25 each | $25. | $12. |
| No. 2 | | $20 each | | | | $22.50 | $10. |
| No. 3 | [a] | $18 each | | | | $20. | $9. |
| Wheelbarrows, Pan-American (all steel, $15.) | $2.50 to $6.50 each. | $12.50 | $7.50 to $12.50. | $20 each | $15 each | $20. | |
| Wagons (Bain) | | $160 to $180. | | | | $200. | |
| Leather | 40 to 45 cts. per lb. | $1 per lb | $1 per lb. | | | $1.25 per lb. | |
| Self-dumping carriers: | | | | | | | |
| Made in San Francisco [b] | | | | | | $80 to $90. | |
| Made in Dawson | | $75. | | | | | |
| Pilot bread | $1.65 per 27-lb. box. | 15 cts. per lb. | 25 cts. per lb. | 40 cts. per lb. | 30 cts. per lb. | 20 cts. per lb. | 10 cts. per lb. |
| Flour | $2.90 per 100 lbs. | $6.50 per 100 lbs. | $7 per cwt. | $15 per cwt | $11 per cwt | $9 per 100 lbs. | $3.25 per cwt. |
| Rolled oats | 45 cts. per 10-lb. sack. | 8 cts. per lb. | $9 to $10 per cwt. | $17 per cwt | $17 per cwt | 13½ cts. per lb. | 4½ cts. per lb. |
| Corn meal | 35 cts. per 10-lb. sack. | 7 cts. per lb. | $9 to $10 per cwt. | $17 per cwt | $18 per cwt | 13½ cts. per lb. | 4 cts. per lb. |
| Evaporated cream | $4.40 case of 4 doz. | $7.50 per case | $2.50 per doz. | $20 per case | $13 per case | $12 per case. | $4.50 to $5.50 per case. |
| Beans | 4 cts. per lb. | 8 to 9 cts. per lb. | $10 per cwt | 20 cts. per lb. | 14 cts. per lb. | $13.50 per cwt. | 5 to 6 cts. per lb. |
| Ham | 16 cts. per lb. | 25 cts. per lb. | $40 per cwt | 60 cts. per lb. | 40 cts. per lb. | 30 cts. per lb. | 18 cts. per lb. |
| Bacon | 18 to 20 cts. per lb. | 25 cts. per lb. | $35 per cwt | 60 cts. per lb. | 40 cts. per lb. | 30 cts. per lb. | 18 cts. per lb. |
| Fresh beef, by side | 11 cts. per lb. and up. | 25 cts. per lb. | 30 to 50 cts. per lb. | | | | 25 to 35 cts. per lb. |
| Coffee | 15 to 35 cts. per lb. | 40 to 65 cts. per lb. | 50 cts. per lb. | 75 cts. per lb. | 60 cts. per lb. | 75 cts. per lb. | 15 to 50 cts. per lb. |
| Tea | 25 to 60 cts. | 40 to 65 cts. per lb. | 75 cts. to $1 per lb. | $1.25 per lb | $1.05 per lb. | 75 cts. to $1 per lb. | 25 cts. to $1. per lb. |
| Salt | 2½ cts | 6 to 7½ cts. per lb. | $10 per cwt | | | 10 cts. per lb. | 4 cts. per lb. |
| Pickled pork | 12 cts. per lb. and up. | $25 per 100 lbs. | | | | 30 cts. per lb. | 13 to 15½ cts. per lb. |
| Potatoes, fresh | $1.75 per 100 lbs. | 7 to 9 cts. per lb. | $11 per cwt | | | 10 cts. per lb. | 4 to 5 cts. per lb. |
| Onions, fresh | 2½ cts. per lb | 9 to 10 cts. per lb. | $15 per cwt | | | | 4 to 5 cts. per lb. |
| Eggs, fresh | 30 cts. per doz. | $12 to $15 per case. | $18 per case of 30 doz. | | | $25 per case. | $10 to $15 per case. |

[a] 5-inch pump, weighs 1,131 pounds; 6-inch pump, 1,417 pounds; 8-inch pump, 1,990 pounds; 10-inch pump, 3,130 pounds.
[b] Made with self-lubricating sheave, extra hammer, $7; extra sheave, $5.

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TABLE 30.—*Prices of mining supplies in the North*—Continued.

| | Juneau. | Dawson. | Circle. | Mastodon post-office, Birch Creek region. | | Fairbanks. | Nome. |
|---|---|---|---|---|---|---|---|
| | | | | Summer. | Winter. | | |
| Hay | $35 to $40 per ton. | $90 per ton | $100 per ton | | | $160 per ton | $50 per ton. |
| Oats | $40 per ton | $100 per ton | $110 per ton | | | $160 per ton | $50 per ton. |
| Overalls | 75 cts. per pair | $1.25 | $15 per doz | | | $1.80 | $1. |
| Jumpers | $1 each | $1.50 | $15 per doz | | | $1.80 | $1. |
| Leather miners' shoes | $3.75 per pair | $4 to $6 per pair | $4 to $7 per pair | | | $6 per pair | $4 to $12. |
| Gold Seal rubber boots | $8 per pair | $11 per pair | $10 | | | $12 | $8. |
| Gold Seal rubber shoes | $3 per pair | $3.50 per pair | $4.50 | | | $5 | $3.50 to $5. |
| Blankets (all wool) | $2.50 to $10 per pair | $10 | $5 to $15 | | | $10 | $3 to $15. |
| Duck | 12½ to 20 cts. per yd. | 25 cts. to $1.25 per yd. | 33⅓ to 60 cts. per yd. | | | 50 cts. per yd | |
| Sweaters | $1.50 to $3.50 each. | $2.50 to $6 | | | | $4.50 each | $2.50. |
| German socks | $0.75 to $1.50 per pair. | $1 per pair | $1 to $2 | | | $2.25 | $1.25 to $1.50. |
| Slicker coats | $2.50 each | $3.50 | | | | | |

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## LEGAL CONDITIONS IN 1904.[a]

### INTRODUCTION.

After an investigation of the present conditions in the new so-called Fairbanks district of Alaska, situated on Tanana River, I was forcibly impressed with the urgent need of a change in the present location law, which allows the location of placer tracts by representation. An individual holding twenty or fifty powers of attorney from other citizens of the United States may go alone into a wild and unknown district and, by staking claims, each of 20 acres, tie up whole creek valleys which are by this process withdrawn from the area of public lands for a period generally amounting to eighteen months.

The location of the claims is then recorded in the nearest recording office in the names of the men who may be in San Francisco, Chicago, or New York. The ownership of the claims may afterwards be changed ad libitum by the passing of quitclaim deeds. The locator can have, under the law, but one claim by right of location on each creek; but by exercising the right of representation he withdraws from the public domain as many miles of creek beds as he can traverse and stake. On each claim he is required to do no work, beyond sinking a small discovery shaft, for the remainder of the year in which the location is made and up to the end of the ensuing year. Thus in any placer district in which the auriferous gravels have an economic value, and into which prospectors are continually pouring, as in the new Fairbanks district, many bona fide miners willing to search for gold to the extent of their physical and financial resources are rendered powerless through circumstances which they can in no way control or by any possibility foresee.

These men, willing to undergo the discomforts of an inhospitable country, either find themselves idle in a remote community, where living is expensive, or are compelled to make journeys of four or five days' duration from the base of supplies, and pack their provisions, blankets, and tools on their backs to find ground that has not been staked.

It may be objected that each man has an equal opportunity to reach a given piece of ground first. This, however, is hardly the case. The resources of the men who unite to send an individual to locate for them by power of attorney are generally greater than those of the individual who singly goes out with the purpose of locating one claim for his own operations. The power-of-attorney man, equipped with a better outfit and very likely dogs or horses, can go farther and stay longer than the prospector of limited resources.

[a] I have discussed at some length the legal conditions of mining and the abuses prevailing under the present law in Alaska in a report made to the "Public Lands Commission," recently appointed by the President. In the same report I have embodied suggestions for a revision of the present law as far as it pertains to placer mines in Alaska.

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Furthermore, the man who locates for others, if he does not represent persons living altogether at a distance, is frequently sent out by men whose interests are entirely inimical to the proper development of the region—namely, saloon keepers, nonproducers, "tin horns" (gamblers), or other riffraff such as are generally found in the new American mining camp. They have rarely the intention of operating the claims located in their names and thus producing gold. They hold the claims in the hope that the camp will boom, that inexperienced outsiders will come in, and that in the ensuing excitement they may sell at a figure based on the supposed value of the unprospected ground.

In the Fairbanks district portions of 3-mile stretches on three creeks are producing gold. Other portions within this producing area, as well as lengths of from 3 to 10 miles on six other creeks, are hardly prospected, are not producing, and are entirely withdrawn at present from exploration or exploitation through the process of the empowered staking above referred to. It is estimated that 2,000 persons will spend the winter in the district. Of these at least 1,200 will be able-bodied workingmen. The operations will afford work for possibly 600 men. One-half the remainder at least would prospect and develop new territory were it not for the nearly insuperable difficulties. The provisions of the present location law are, in my opinion, largely responsible for these difficulties.

In the portion of the Alaska interior lying between Yukon and Tanana rivers the auriferous gravels occupy a wide area. The overcoming of the purely physical obstacles to exploration is arduous, and many miles of creek valleys will be located as means of communication become established. If this large area and other areas yet to be explored are allowed to be progressively withdrawn from possible gold production, the result will be a distinct detriment to the development of Alaska.

A confirmation of the annoying and injurious effects of the law is afforded by the early history of the Nome gold district of Seward Peninsula, where the conditions were as follows:

> Nearly every individual located not only for himself but also for his many friends by power of attorney. To such an extent was the power of attorney here abused that more than 7,000 acres of ground were located, so that the several thousand Americans who arrived later, finding no unstaked ground anywhere in the vicinity, justly raised a somewhat bitter complaint.[a]

The practice of exercising the power of attorney is increasing in Alaska at present, and its abuse warrants the summary suspension of it if this be possible.

In September I visited the principal creeks on which gold-mining operations are being prosecuted in the Nome, Solomon, and Council

[a] Schrader, F. C., and Brooks, A. H., Preliminary Report on the Cape Nome Gold Region, U. S. Geol. Survey, 1900, p. 32.

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districts of Seward Peninsula. Although the investigation of the legal conditions pertaining to gold mining was not called for by my instructions, certain facts regarding these conditions were impressed upon me. Indeed, it is impossible for an observer, impartially disposed, to go about the mining districts of Seward Peninsula and not seriously question the applicability of the present location law to Alaska conditions.

It is true that $100 worth of work is by law actually required on each 20 acres, but the statute is so loosely framed that the $100 worth of work is now done universally on each 160 acres, not only in Alaska but in all parts of the United States where placer mining is conducted. Moreover I have observed that this $100 worth of assessment work in all mining territory is little more than a farce. The suggestion that $100 on each 20-acre tract be used in making survey and plat of the claim the first year is worthy of consideration.

## APPLICATION OF THE PRESENT MINING LAW TO ALASKA.

The following order of the Secretary of the Interior, dated July 28, 1885 (Land Office Decisions, vol. 4, p. 128) extended the regulations of the General Land Office to Alaska.

In pursuance of the eighth section of the act of Congress, approved May 17, 1884, entitled "An act to provide a civil government for Alaska" (23 Stat., 24), it is hereby prescribed that the rules and regulations of the General Land Office and Department of the Interior governing the administration of the mining laws of the United States be adopted for and extended to the district of Alaska, so far as the same may be applicable.

It is evident that the various provisions in Revised Statutes, Title XXXII, chapter 6, defining the United States mining laws, apply fully to Alaska.

SEC. 2329. Claims usually called placers, including all forms of deposit, except veins of quartz, or other rock in place, shall be subject to entry and patent under like circumstances and conditions as are provided for vein or lode claims.

Lindley on Mines says (vol. 1, sec. 432) that this has been construed to mean:

(1) That there must be a discovery upon which to base the location.

(2) The location must be marked upon the ground so that its boundaries can be readily traced.

### DISCOVERY.

According to the accepted interpretation of the law in the mining States of the United States, gold must be found on the ground in a discovery shaft before the claim can be validly held by location.

That many of the Alaska locations are illegal may be judged from the fact that very often three men have staked from ten to twenty 160-acre tracts of placer ground within periods varying from twenty-



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four to seventy-two hours. On every one of these tracts under the correct interpretation of the law, a shaft or drill hole at least 15 feet in depth would have been necessary in order to find one color of gold. Yet the same men have immediately recorded their staked ground as locations, swearing that they discovered gold. Lindley states (sec. 437): "The Land Department has uniformly held that discovery is essential in the case of placers, going so far at one time as to hold that such discovery was essential in each 20-acre tract within a location of 160 acres located by an association of persons." He further says: "Discovery is just as essential in case of placers as it is in lode locations."

The regulations of the General Land Office include the following:

No lode claim shall be located until after the discovery of a vein or lode (or in a placer of gold) within the limits of the claim, the object of which provision is evidently to prevent the appropriation of presumed mineral ground for speculative purposes to the exclusion of bona fide prospectors before sufficient work has been done to determine whether a vein or lode (of gold) really exists. [a]

The nonobservance of the above requirement, and, in fact, the impossibility under the present law of its enforcement is the cause of the very evil in Alaska which the law aims to avert. I regard the promiscuous location and illegal holding of land on which gold has not been discovered as one of the most serious detriments to Alaskan development.

### SUBSEQUENT ANNUAL LABOR.

Regarding subsequent labor Lindley (sec. 624) makes the following statement:

While a timely resumption of work may prevent a relocation, the law contemplates that the labor or improvements, actual and valuable, to the amount of $100 in each year, computed from the 1st day of January next succeeding the date of location, should be performed in good faith. There is probably no single provision of the law which is evaded to a greater extent than this one. While, of course, there are many exceptions the average locator exhausts his ingenuity in attempting to avoid this plain and wholesome requirement. The courts are disposed to deal with these drones in the hive with much more leniency than they deserve. The statute is too frequently applied on sentimental lines. Forfeitures, say these tribunals, are odious, and in many cases the reluctance with which they enforce the law encourages rather than deters the systematic evasion of it.

The statute is extremely liberal as to the time in which the specified amount of work shall be performed. A location made on January 1, 1897, may, in the absence of State laws or local rules requiring development work to be performed as an act of location, [b] be held without a stroke of labor until December 31, 1898, and in no case

[a] Mining laws and regulations, General Land Office, 1903, p. 27, §8.

[b] It should be borne in mind that the principal Western States where mining is conducted have, by State legislation, so enlarged upon the rather bare fabric of the Federal mining law that, within the boundaries of these States many of the abuses which are permissible under a liberal interpretation of the Federal law, have been done away with. On the other hand, the excellent restrictions in force in the placer-mining States have no force in Alaska, and in consequence decisions rendered by the courts must be much more liberal, and are productive of the evils for the obviation of which the State statutes were long ago enacted.—C. W. P.

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is the period less than a full year. It would seem that a more rigid enforcement of the rule would not only command more respect for the law, but would in a great degree tend to promote the general object and intent of the mining statutes—the development of the mining resources of the country.

The above quotations are made because the opinions so closely bear on the deplorable conditions in Alaska. The climatic conditions are so formidable on the 31st of December of each year (the date of expiration of the time in which a miner may do his annual assessment work) that $100 might be expended by him in work on the claim in merely shoveling snow. Naturally, all traces of the work so done would be obliterated in a short time; yet it would be actual and valuable work, for otherwise he could not reach the ground beneath. This feature is so well understood in Alaska that a man who makes affidavit to work done holds his claim from year to year unquestioned, and it is undoubtedly true that the bulk of the territory held as placer ground is not only unworked but unvisited by the claimants after first location. Should, however, an individual relocate or "jump" a given claim so held, the first holder goes into court and swears that he has done his annual representation work, thus maintaining his title. Should the relocator maintain that he has searched the ground and found no traces of any previous work, he still has a weak case, and the verdict is usually against him. It is needless to say that this relocator has, in the great majority of cases, the better right to the ground.

I have endeavored to make clear a few of the reasons why the production of gold is actually retarded in Alaska, rather than assisted, by the present administration of the mining law.

## BOUNDARIES.

Of over a thousand prospectors in California, Oregon, Nevada, Colorado, Idaho, Montana, and Alaska whom I have known, talked with, and been in the field with, I have never seen ten who included a compass in their equipment, to say nothing of surveying instruments more nearly approaching precision. These men, generally known among themselves as "practical miners," are of the class by which mineral locations are generally made. Is it fair to assume that such men are competent to make a location which shall conform to the mining regulation?

His location notice should give the course and distance as nearly as practicable from the discovery shaft on the claim to some permanent well-known points or objects, such, for instance, as stone monuments, blazed trees, the confluence of streams, point of intersection of well-known gulches, ravines, or roads, prominent buttes, hills, etc., which may be in the immediate vicinity, and which will serve to perpetuate and fix the locus of the claim and render it susceptible of identification from the description thereof given in the record of locations in the district, and should be duly recorded.[a]

[a] U. S. Mining Laws and Regulations—General Land Office, 1903, p. 27, sec. 9.

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In Alaska, at least, the provisions called for by the above have become practically a dead letter, as is instanced by the case of the prospectors who during the season of 1903 were allowed to locate a group of claims defined as being on "Midas Creek, a tributary of a tributary of Koyukuk River." Midas Creek and the supposed locations afterwards proved to be entirely mythical.

The location law requires that the "location must be distinctly marked on the ground, so that its boundaries can be readily traced." How can the following decision of the Supreme Court of the United States, in the case of the McKinley Creek Mining Co. *v.* Alaska United Mining Co.,[a] which sustained the validity of a placer location where no attempt was made to actually mark the boundaries, be reconciled with the above? Lindley says:

> All that was done was to post notices on a snag or stump in a creek, claiming a certain number of feet running with the creek, and 300 feet on each side of the center of the creek, and referring to the claim as "the east extension of a certain-named claim and the west extension of another." Unless some facts or circumstances were represented to the court which can not be gleaned from the official report of the case, such a location would seem to fall short of the requirement that the claim shall be "distinctly marked on the ground, so that its boundaries may be readily traced."

I have no hesitation in saying that in Alaska, especially in Seward Peninsula, no attempt is ordinarily made by the locator to mark the boundaries of claims beyond the setting of stakes at the four corners averaging 3 feet in length by 1½ inches in diameter. These are generally overturned by the wind or uprooted by the frost within six months of the time of setting. And yet the burden of proof in case of subsequent dispute always rests on the relocator or the jumper.

I will call attention to the fact that the suggestions leading to modification in the present placer-mining law are directed to the reforming of the principal abuses which have been cited. Had time permitted, instances of abuse and misinterpretation of the present laws might have been indefinitely multiplied. Enough has been said to show that changes of a radical nature are needed in the laws and their administration, in order that the undoubtedly valuable mineral resources of Alaska may be exploited to the best advantage.

Much fault has been found in past years with the Territorial administration in the Klondike. That conditions affecting title have at times left much to be desired is undoubtedly true. At present efforts are being made to remedy the abuses which exist. In Alaska, on the other hand, each rich discovery of gold brings forth one or more lawsuits, and each new camp that is developed affords a profitable field of exploitation for swarms of parasites who, too indolent or too ignorant to devote themselves to bona fide mining, ingeniously strive, by manifold ways of trickery, to live by the labor of others.

[a] Cited by Lindley, sec. 373.

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[Bulletin No. 263.]

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COLLIER, ARTHUR J. Placer mines of Seward Peninsula.
——— Coal field of Cape Lisburne.
MARTIN, G. C. The geology of Alaska Peninsula.
MOFFIT, F. H. The Cook Inlet gold placers.
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SCHRADER, F. C. The geology of upper Copper and Tanana rivers.
STONE, R. W. The Kachemak Bay coal fields.
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WRIGHT, C. W. The mineral resources of Admiralty Island.
WRIGHT, F. E. The mineral resources of the Wrangell district.
——— The mineral resources of the Sitka district.

TOPOGRAPHIC MAPS OF ALASKA.

The following maps are on sale at 5 cents a copy, or $2 a hundred:

BARNARD, E. C. Fortymile quandrangle; scale, 1:250000.
PETERS, W. J. Juneau special quadrangle; scale, 1:63500.

The following maps are included as illustrations of published reports, but have not been issued separately. They can be obtained only by securing the report:

BARNARD, E. C. Cape Nome and adjacent gold fields; scale, 1:250000. Contained in a special publication of the U. S. Geol. Survey, entitled "Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900," Washington, Government Printing Office, 1901.
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GERDINE, T. G. Koyukuk and Chandlar rivers, portions of; scale, 1:625000. Contained in "Preliminary report of a reconnaissance along the Chandlar and Koyukuk rivers, Alaska, in 1899." Twenty-first Ann. Rept., pt. 2, 1900.
——— Seward Peninsula, northwestern part of; scale, 1:250000. Contained in Professional Paper No. 2.
——— Fairbanks and Birch Creek districts, reconnaissance maps of; scale, 1:250000. Contained in "The gold placers of Fortymile, Birch Creek, and Fairbanks districts." Bulletin No. 251.
——— Yukon-Tanana region, reconnaissance map of; scale, 1:625000.
——— Copper and upper Chistochina rivers; scale, 1:250000. Contained in "A geology of the central Copper River basin." Professional Paper No. 41.
——— and WITHERSPOON, D. C. Chitina and lower Copper River region; scale, 1:250000. Contained in "The geology and mineral resources of a portion of the Copper River district, Alaska." Special Publication of the U. S. Geol. Survey, Washington, Government Printing Office, 1901.
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MENDENHALL, W. C. Cook Inlet, head of, to the Tanana via Matanuska and Delta rivers, also part of Kenai Peninsula; scale, 1:625000. Contained in "A reconnaissance from Resurrection Bay to Tanana River, Alaska, in 1898." Twentieth Ann. Rept., pt. 7, pp. 265–340.
MULDROW, ROBERT. Sushitna River and adjacent territory; scale, 1:625000. Contained in "A reconnaissance in the Sushitna basin and adjacent territory, Alaska, in 1898." Twentieth Ann. Rept., pt. 7, 1900, pp. 1–29.

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PETERS, W. J. Tanana and White rivers, portions of; scale, 1:625000. Contained in "A reconnaissance in the Tanana and White River basins, Alaska, in 1898." Twentieth Ann. Rept., pt. 7, 1900, pp. 425–494.

——— Lynn canal, routes from, via headwaters of White and Tanana rivers to Eagle City; scale, 1:625000. Contained in "A reconnaissance from Pyramid Harbor to Eagle City, Alaska." Twenty-first Ann. Rept., pt. 2, 1900, pp. 331–391.

——— Norton Bay region; scale, 1:625000. Contained in "Reconnaissances of Cape Nome and Norton Bay regions, Alaska," 1900.

——— Koyukuk River to mouth of Colville River, including John River; scale, 1:625000. Included in Professional Paper No. 20.

POST, W. S. Cook Inlet, region from head of, to Kuskokwim River and down the Kuskokwim to Bering Sea, Bristol Bay, and a part of Alaska Peninsula; scale, 1:625000. Published in sections in "A reconnaissance in Southwestern Alaska, in 1898." Twentieth Ann. Rept., pt. 7, 1900, pp. 31–264.

READURN, D. L. The Mount McKinley region; scale, 1:250000. Contained in Professional Paper No. —.

WITHERSPOON, D. C. Copper, Nabesna, and Chisana rivers, headwaters of; scale, 1:250000. Contained in "The geology of the central Copper River region." Professional Paper No. 41.

——— Seward Peninsula, northeastern portion of, topographic reconnaissance of; scale, 1:250000. Contained in "The Fairhaven gold placers, Seward Peninsula." Bull. No. 247.

TOPOGRAPHIC MAPS OF ALASKA IN PREPARATION.

WITHERSPOON, D. C. The Fairbanks placer district; scale, 1:250000.

GERDINE, T. G. The Nome district; scale, 1:62500.

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DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

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# RECORD OF DEEP WELL DRILLING FOR 1904

BY

M. L. FULLER, E. F. LINES, and A. C. VEATCH



WASHINGTON
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1905

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# LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
HYDROGRAPHIC BRANCH.
*Washington, D. C., February 13, 1905.*

SIR: I have the honor to transmit herewith a manuscript entitled "Record of Deep Well Drilling for 1904," prepared by Messrs. M. L. Fuller and E. F. Lines, but including certain material compiled from notes furnished by Mr. A. C. Veatch. The report presents the results of the first six months' work, with a system for the collection of well records and samples, formulated by Mr. Veatch and put in operation under the direction of Mr. Fuller, chief of the eastern section of the division of hydrology, on July 10, 1904. Mr. Veatch was assisted by Mr. Lines until September 15, when the work was relinquished to the latter. The report embodies the records of a large number of wells, for many of which sets of samples are preserved on file, and in addition gives an account of the development of the system and of the methods employed.

The principal aim of the report, as stated in the introduction, is to furnish drillers and present or prospective well owners a basis for future work and to afford geologists and others a more complete knowledge of the rock succession and structure. It is hoped that the report will lead to greater appreciation of the value of records by the driller and will serve to encourage the preservation of samples.

Very respectfully,

F. H. NEWELL, *Chief Engineer.*

Hon. CHARLES D. WALCOTT,
*Director United States Geological Survey.*



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# RECORD OF DEEP WELL DRILLING FOR 1904.

By M. L. FULLER, E. F. LINES, and A. C. VEATCH.

## INTRODUCTION.

In this report, which is the first of a proposed series of annual publications, are presented the results of the first six months' work by the United States Geological Survey in the systematic collection of well records and samples. Much time having been occupied in organization and preliminary correspondence, the results of only about three months' actual work are included. The report is issued for the purpose of giving to present or prospective well owners and drillers the results of drilling as reported to the Survey, with the object of furnishing them as good a basis as possible for future drilling in the regions discussed, and to afford geologists and others a more complete knowledge of the rock succession and structure.

It is intended that the reports of the series shall present records of contemporaneous drilling rather than the results of past work, a special attempt being made to secure records accompanied by samples. The logs of completed wells, however, will be incorporated when practicable; but as records of such wells are seldom preserved for any length of time, their number will probably decrease in proportion to new wells as the work continues.

All well records received during the year 1904 that were accompanied by complete sets of samples are presented in this report, as are also a considerable number furnished by drillers, contractors, well owners, etc., representing other completed wells. The report does not, however, include all records furnished the Survey, a great number being furnished by oil companies and others interested in the development of oil or mineral lands. Many of these are confidential and can not be published, while others will be compiled and embodied in reports on special regions, which will be published later.

Grateful acknowledgment is made to the following contractors and drillers who, by furnishing records or samples, have assisted the Survey in its endeavor to bring about a better knowledge of the strata penetrated in drilling. The asterisk (*) indicates that records of wells are given in whole or in part in the present report; in the other cases the records are either confidential or are reserved for special reports to be published later.



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*Principal contractors and drillers furnishing records.*

Aggers, William A., Muscogee, Ind. T.
Akin, Mr., Wade avenue, Washington, Pa.
*Akins, E. J., driller for Reece, Heasley & Meals, Hundred, W. Va.
Archer, Kruger, Mississippi.
*Artesian Well and Supply Company, Dyer and Friendship streets, Providence, R. I.
*Barber, Lucien C., Scott, Cortland County, N. Y.
Barnes, R. B., Artesia, N. Mex.
Beach, O. C., Roswell, N. Mex.
*Bean, J. S., R. F. D. 65, Emlenton, Pa.
Birdsong, Mason, Bolton, Miss.
Bishop, Mr., Salt Lake City, Utah.
Black, Frank L., Waynesburg, Pa.
*Black, R. H., 423 John street, Braddock, Pa.
*Bliss, George R., Rye, N. Y.
*Bolles, William M., Franksville, Wis.
Borchers, W. F., 68 East Maiden street, Washington, Pa.
Brigham, W. J., Tunica, Miss.
Broiles, E., Artesia, N. Mex.
*Carman, George W., driller for G. W. Patterson, Stewartstown, Pa.
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Carter Oil Company, Titusville, Pa.
*Champlin, F. A., East Longmeadow, Mass.
Chapman & Sperry, Artesia, N. Mex.
Chartiers Oil Company, Tradesmen's Building, Pittsburg, Pa.
Chesney & McCready, Muscogee, Ind. T.
*Christofferson, E., driller for J. F. McCarthy, Fertile, Minn.
*Cladek, Frank T., West Scott avenue, Rahway, N. J.
*Clifton, R. T., Velasco, Tex.
*Colwell, J. A., West Superior, Wis.
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Cooper & Warren, Roswell, N. Mex.
*Copley, W. H., 828 Leonard street, Fostoria, Ohio.
*Craig, L. J., Rock Springs, Wyo.
Crane, G. S., Checotah, Ind. T.
*Crist, S. T., and Son, Codorus, York County, Pa.
Cunningham, J. B., Cliftonville, Miss.
*Danis, C. H., Coldspring Harbor, N. Y.
Devonian Oil Company, Pittsburg, Pa.
*Dibble & Ernest, Fullertown, Ohio.
*Dillon, J. B., Bowen, Pike County, Ark.
*Duck, Elmer J., driller for John McCool, New Freeport, Greene County, Pa.
*Dunlap, T. L., driller for J. B. Fishel, New Martinsville, W. Va.
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Durst, F. A., Bellefourche, S. Dak.
*Eagen, Thomas, Poynette, Wis.
*Egan, James, driller for F. A. Champlin, Mansion House, Springfield, Mass.
Eisman, David, Washington Trust Building, Washington, Pa.
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Endly, W. J., Nowata, Ind. T.
English, A. Z., Muscogee, Ind. T.
*Espy, E., driller for J. F. McCarthy, Atwater, Minn.
*Faust, J. J., South Kaukauna, Wis.

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Feigler, C. E., Minter City, Miss.
*Ford, John L., driller for J. A. Sutter, Pass Christian, Miss.
Forest Oil Company, 323 Fourth avenue, Pittsburg, Pa.
Forman, Grant, Muscogee, Ind. T.
*Fowler, Thomas, Corpus Christi, Tex.
Fox, J. A., Roswell, N. Mex.
Franklin Oil Company, Tyro, Kans.
Garner & Swerringen, Artesia, N. Mex.
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Kelly Bros. & Cooper, Beaver, Pa.
Kennedy, W. C. & Co., Pittsburg, Pa.
*Kinney, James, jr., Bellaire, Ohio.
Klinkscale, Mr., Roswell, N. Mex.
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*McDonald, R. H., driller for C. E. Gesin, Tidioute, Pa.
*McGuckin, J. B., driller for Thomas B. Harper, 5921 Beechwood street, Philadelphia, Pa.
McVay Brothers, Rockyford, Colo.
*Matteson & Zeigler, Bonsteel, S. Dak.
*Maule, Lewis, Copemish, Manistee County, Mich.
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Pinchin, Job, Salt Lake City, Utah.
Poland, C. E., Hagerman, N. Mex.
Pond, Chester H., Moorhead, Miss.
Prairie Oil and Gas Company, Neodesha, Kans.
Preston, John, 322 Washington Trust Building, Washington, Pa.
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*Pursell, T. A., Waukena, Tulare County, Cal.
Pyle, P. L., Fort Gibson, Ind. T.
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*Sutter, Frank, Pensacola, Fla.
*Sutter, John A., Pass Christian, Miss.
Taylor, D. J., Roswell, N. Mex.
*Taylor, Fred, Grandville, Mich.
*Teeter, W. G., North Salem avenue, Dayton, Ohio.
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*Tomlin, James, Mars, Oreg.
*Tracy, Albert, Orrville, Ohio.
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*Watkins & Co., Vancamp, W. Va.
*Weiler Brothers, Box 367, Marietta, Ohio.
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Westphal, Gus, Salt Lake City, Utah.
White, Elza, Roswell, N. Mex.
Willetts, Elmer E., 186 South Main street, Washington, Pa.
*Winger, Josiah G., Box 135, Grand Valley, Pa.
Yager, Frank, Salt Lake City, Utah.

In addition to the drillers furnishing records and samples, special thanks are due to the owners of many wells, through whose courtesy and by whose orders many of the samples and records were furnished the Survey. The names of the owners are given in the tables of records, those furnishing records being indicated by the letter "O" in the column headed "Authority."

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# OBJECTS, DEVELOPMENT, AND RESULTS OF THE WORK OF COLLECTING WELL RECORDS AND SAMPLES.

By MYRON L. FULLER.

The information relating to borings must generally be gathered when the well is being sunk or not at all. Many drillers keep records when the work is going on, but in the majority of cases these are soon lost. If the driller continues work in a single locality he soon comes to know perfectly the main points of the succession of the rocks and keeps no records, often even throwing away his earlier ones. In other cases he may remove to other regions, and, having no further personal interest in the original locality, the early records are lost or destroyed. Only the larger operators keep permanent records of their wells. For these reasons the effort is now being made by the Survey to secure the record at the time of drilling and to supplement it wherever possible by actual samples, which will be filed and made permanently accessible for use whenever questions arise regarding the materials encountered.

## IMPORTANCE OF ACCURATE WELL RECORDS.

The knowledge of conditions beneath the surface, whether sought by the driller, the mining engineer, or the geologist, must be obtained either from surface observations of rock outcrops or from artificial sections afforded by mine or other shafts, inclines, tunnels, and borings. By systematic observations upon the character of the rocks over extended areas and the determinations of their inclination (dip) and their line of outcrop on level surfaces (strike), the trained observer is able to calculate more or less accurately the thickness of the beds, their depth below the surface, their structure, and to a certain extent their character as regards the occurrence of gas, oil, brine, or fresh water, especially the latter. The thickness and composition of rocks, even of the same bed, are not constant, but undergo changes, often considerable in amount and taking place within short distances. These changes are frequently of great importance in their effect upon the occurrence of the products named. Where the rocks are at the surface the changes can be easily recognized, but when below the surface only



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the shaft or drill can determine the occurrence and nature of the changes in question.

The shaft is of immense value in restricted areas, but it is the widely distributed and often deep borings that afford information in regard to the broader features of interest to the driller, to the operator in search of oil, gas, or brines, and to manufacturers and others seeking artesian waters.

The importance of accurate records of borings was early recognized by the more enterprising of the drillers and by certain companies operating in oil and gas, and the success of such drillers and operators has been to a considerable extent due to their recognition of the importance of the precise information afforded by the borings, their insistence that records be kept, and their attention to other similar details, minor in themselves but often sufficiently important in the aggregate to make the difference between failure and success. It is probable that there is now not one successful operator on a large scale who does not require the keeping of at least partial records.

Among the many ways in which well records are of value the following may be mentioned: To the oil and gas driller they furnish information as to (1) the best point for locating the well, (2) the depth of the supposed productive bed, (3) the character of the material to be penetrated, (4) the amount of water which will be encountered, (5) the amount of casing required, and (6) the limit of depth to which it is desirable to drill. To the owners of such wells information as to each of the foregoing points, especially those affecting the cost of the wells, is furnished by the records, in addition to which data relating to still more important factors, namely, those of quantity and quality of supplies, are furnished. In the case of drillers and owners of water wells the same information is supplied, but here the items affecting the cost are of increased importance owing to the lower value of the product, and questions of head, quantity, and quality of supply again come to the fore. To prospective owners records show the results obtained by others and the probabilities of success of new ventures, while to the geologist they are of value in assisting him to a more thorough understanding of the geology, which in turn enables him to more intelligently answer the numerous questions constantly referred to him by drillers, well owners, and others.

A more detailed statement concerning the uses of records is given in the following paragraphs, with the view of presenting their benefits more fully to those drillers and owners, especially the smaller operators, who do not have the facilities of the larger companies for collecting and preserving their own records, but who by furnishing information can assist the Survey to a knowledge of the various regions, and thus enable it in turn to give them the benefit of the results of the studies of its geologists.

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## VALUE OF WELL RECORDS TO THE DRILLER FOR OIL AND GAS.

The contractor or driller for oil or gas is often called upon to sink wells in regions wholly unfamiliar to him. Among the questions which will arise are the following: (1) What is the depth of the supposed oil- or gas-bearing rock? (2) What is the character of material to be penetrated before reaching it? (3) At what depths, in what amounts, and of what quality can water for the boilers be obtained? (4) What is the depth of water seams which must be cased off? (5) What are the character, depth, and thickness of rock which will require casing to prevent caving, if any? (6) At what depth and in what rock is it advisable to stop drilling in case of failure to strike oil or gas at the expected point? (7) At what depths will minor shows of oil and gas be encountered? In case the contractor or driller is required to select the spot for drilling, another question will arise: (8) At what point is the structure most favorable for the occurrence of oil and gas?

A certain amount of this information can be obtained, as has been pointed out, by observation of the character, dip, and strike of the rocks exposed at the surface. Other data, especially those relating to the occurrence of water, to caving rock, and to the depth at which it is advisable to stop drilling, are best derived from records of borings. These need not, however, be necessarily in the immediate vicinity, for a geologist or a driller with a practical working knowledge of the simpler principles of geology can combine the observations afforded by surface outcrops with records of borings at a distance, and intelligently predict the conditions in the intervening area.

*Depth of productive rock.*—The depth to the productive rock is of great importance as affecting the success of a well. For a shallow well a relatively light outfit can be used, but for deeper borings heavy and more costly machinery and rigs are required. These, with increased cost of fuel, outfit, casing, and greater difficulty of manipulation, make the cost of a well increase rapidly with depth. The amount of oil or gas which would give a good profit on the investment required for a 1,000-foot well might not be sufficient to warrant the sinking of a 3,000-foot well.

It is apparent, therefore, that as close an estimate of the depth as possible should be made before starting to drill. This may in some cases be determined more or less satisfactorily by observation of the distance of the well from the outcrop of the rock and determination of the direction and amount of the dips at the outcrop and in the area intervening between it and the well, but in many instances the outcrop is several score, if not hundreds, of miles from the well, and there are many irregularities of dip and changes of thickness of the rocks in the intervening area, all of which serve to make computations from surface data difficult and unreliable.

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On the other hand, deep drilling has been so extensively conducted in this country, especially in the East, that there are very few regions of any extent that do not have one or more deep borings. These furnish, where the data have been preserved, our best evidence of underground conditions, and, combined with surface observations, form a basis for predicting the materials to be encountered in new borings. Where there are a number of borings they afford accurate data for the calculation of dip, which as determining structure becomes an all-important factor in oil and gas operations. This is an especially important feature in regions where, as in much of Ohio, the rocks are buried by hundreds of feet of drift and are nowhere exposed to view at the surface. Two wells of known elevations and penetrating a bed at known depths are sufficient to establish the dip in such regions with greater accuracy than if outcrops were present and served as a basis for the determination. With distances and the amount and direction of dip known the depth can, as has already been indicated, be readily predicted at a given point. Without borings this would often be impossible.

*Character of material.*—Of almost as much importance as the depth of a well is the character of the material penetrated. On it depends the nature of the process of drilling employed. In the soft material of the Coastal Plain, as in parts of Alabama, Mississippi, and Louisiana, driving, jet, and rotary processes, either singly or in combination, are used, but none of these are suitable for rock work. If, therefore, a very hard bed is to be penetrated another type of outfit must be provided. The character of the tools and the rig itself must also be adapted to the nature of the material to be penetrated. In rock the rate of drilling varies from a few inches in the harder limestones to over 100 feet a day in certain shales; hence, in contracting for a well, knowledge of the character of the various beds and of their thickness is of the greatest value.

As already intimated, important variations in the character and thickness of the beds may take place underground without there being at the surface any evidence of the changes, and while it is possible to judge, to a certain extent, of the character of the beds beneath the surface from their more or less distant outcrops, by far the most accurate information is that afforded by the borings in the same or adjacent regions.

*Water supplies.*—When wells are located in valleys, or in thickly settled districts, water for boiler use can usually be obtained from streams or the wells of near-by houses. In many of the oil fields, where the wells are frequently located upon the sides or tops of hills or mountains, the question of boiler supplies is important, and small, separate wells are often drilled for this supply. Beyond the ability of the rock to hold water, as indicated by its texture, little is shown by

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the surface outcrop. Nothing as to crevices, joints, local sandy beds, etc., on which so much depends, is indicated. All this can be finally determined only by the drill. In this case a single boring, unless in the immediate vicinity of the proposed new well, will not afford an absolute indication of the conditions, but from a considerable number sunk in the same kind of rock an average is obtained which shows the predominating conditions characterizing the bed. This is especially true of the quality of the water, which will vary greatly in different localities, often without any reference to conditions discoverable at the surface.

*Casing off water.*—Among the factors affecting the sinking of a well is the occurrence of water in quantities necessitating casing it off. This is of importance in determining the amount of casing necessary and its cost, and in determining the size of the original hole in case it is anticipated that several horizons at some distance from one another, each of which may involve a reduction of the size of the casing, will be encountered. As in the case of the water supplies discussed in the preceding paragraph, the most satisfactory information is that furnished by the records of adjacent wells.

*Casing off "cave" rock.*—In many of the older wells in the softer rocks, especially in shales, much trouble was experienced by the walls of the hole caving and stopping up the bore. This difficulty will be recalled by those familiar with the history of the old Dunkard Creek field, in southwestern Pennsylvania, where many of the wells sunk without casing were ruined by the caving of the walls. Even now that the caving is easily preventable by proper casing, a knowledge of the depths and thicknesses of troublesome beds is of importance in determining in advance the questions relating to casing and its effect on the cost of the well. This information is best furnished by records, as in the case of the water horizons already discussed.

*Limits of depth.*—Nothing can be further from the truth than the common fallacy that oil, gas, water, or whatever the driller may be in search of, can be had if the hole is only drilled deep enough. In unaltered porous rocks oil and gas may occur, within certain limits, regardless of depth; but all rocks, of whatever character, if buried deep enough, especially if subjected to the powerful compression incident to the formation of mountains, become altered through the influence of heat and pressure, often into more or less crystalline masses. In such rocks the volatile substances, such as the hydrocarbons, are expelled and it is useless to look in them for deposits of oil or gas. It is also useless to seek for oil in rocks of igneous origin—that is, those which have once been molten—for the conditions of their formation are such as to preclude the formation or retention of oil or similar substances. Nevertheless, wells have not infrequently been

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sunk into such rocks in search of oil, but the uselessness of this is apparent to those who have noted the records of similar wells elsewhere, as well as to geologists and others who understand the nature of the rocks. The value of accurate records in indicating the depth at which it is advisable to stop drilling will be manifest in those cases where altered or igneous rocks, as described above, are encountered, and in general the logs of the deeper borings are of great value in showing the conditions to be expected at great depths.

*Oil and gas shows.*—In drilling, especially where the well is being sunk to a known producing sand, small shows of oil or a little gas are often encountered and passed through without much attention being paid to them. Probably many instances have occurred where valuable flows have been cased off, but one or two examples will suffice. In the region southwest of Olean, N. Y., on the outskirts of the Bradford oil field, the early wells were all sunk to the Bradford sand, at a depth of 1,000 feet or so below the valleys. In some instances shows of oil were noted at a certain depth, but were cased off without it being suspected that a producing sand was present above the Bradford. Later, when the Bradford supplies ran low, it was shown that the sand at the upper oil show could be developed into a producer, now known as the Chipmunk sand. Where accurate records had been preserved, the casing of the old wells was locally removed and both sands drawn upon; but where because of lack of records this could not be done, new wells had to be sunk, at an aggregate cost of many thousands of dollars. Similarly, in the Bellevernon and other gas fields in southwestern Pennsylvania gas flows which would now be of great value were cased off in the old days of high pressure. Where accurate records have been kept, these can be utilized by removing the casing in the old wells, but otherwise new wells must be drilled.

*Structure.*—It has been many years since the anticlinal theory of oil and gas was proposed. This theory postulated the axis of the anticline or crest of the rock arch as the most favorable point for the occurrence of gas, while oil and salt water should be successively encountered in going outward from the crest. While all anticlines do not afford oil or gas, and while oil is often found under somewhat different conditions, as at the point just above where a steep dip changes to flat (at the top of the rock step, as it were), the general principle involved in the theory has not been affected. On the contrary, almost every district, when closely investigated, is shown to agree with these principles, so that at the present time the problems of rock structure are as important as they ever have been in the history of drilling for oil and gas. In no way can the structure be determined so satisfactorily and with such accuracy as by wells or boring records.



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## VALUE OF RECORDS TO OWNERS OF OIL AND GAS WELLS.

The statements which have been made in regard to the benefit of accurate records to drillers for oil and gas apply with added force to the owners of wells, for the ultimate cost of the wells must, in nearly every instance, fall upon them rather than upon the drillers or contractors. The structure, as determining the most favorable points for drilling, the depth of the producing rock, the character of the materials to be penetrated, the available water supplies, the casing required to shut off undesirable water and to support "cave" rock, and the supply obtainable are all of the greatest importance in determining the success or failure of a well. As has been pointed out, this information is best afforded by records of adjacent wells, and the operator will practically always make inquiries in regard to adjacent wells before beginning his own. Frequently these wells will be found to have been drilled many years ago and the records lost. It is to prevent such loss and, instead, to make the information permanently available that the work of collecting records and samples has been undertaken by the Survey.

## VALUE OF RECORDS TO DRILLERS OR OWNERS OF WATER WELLS.

In the same way that records are of value to oil and gas operators they are of benefit to drillers or owners of water wells. The question of the depth of the water-bearing rock, for instance, is of even greater importance than that of the oil or gas sands, because of the relatively low value of the water as compared with oil or gas. With crude petroleum at $1.50 a barrel a supply of only a few barrels a day will give a profit on the investment required for a well of 2,000 or more feet deep, while many hundred barrels of water are required to make even a much shallower well profitable. Moreover, for many manufacturing uses the supply must reach a certain minimum, representing the amount needed for the processes involved, in order to be of any value whatever, while oil, if present in quantities greater than a mere show, can generally be successfully utilized.

The great importance of obtaining water supplies at a moderate depth will be seen when it is remembered that among the competitors of any manufacturing establishment there will always be some who will be able to obtain abundant supplies of the best quality at almost no cost above that of pumping. In such instances the success or failure of an enterprise may depend on obtaining good water at a slight depth. The character of the material to be penetrated and the amount of casing are prominent items in the cost and, therefore, largely determine the success or failure of a well. Other elements, such as head,

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volume, permanency, and quality of the supply, become of great importance, for on them depend the uses to which it may be put.

Upon the head, for instance, depends the height to which the water will rise, thus determining whether or not pumping, with its attendant expense for outfit, fuel, and labor, will be necessary, while the obtaining of water in sufficient volume, or of a certain quality, may, as has been pointed out above, determine the ability of a manufacturer to cope with competitors, or even the very existence of an industry in a given locality. The probability of success can, in many instances, be foretold in advance where records in surrounding regions are available. The importance of this knowledge has been long appreciated by those interested in obtaining supplies for industrial purposes or for the boilers of manufacturing establishments or railroad locomotives.

Wells have for many years been of great importance as a source of water for irrigation at many points in the West, and recently they have been extensively utilized in the cultivation of rice in Louisiana and other States of the Gulf and Atlantic coastal plains. In such regions the information and records afforded by the pioneer wells as to the depth and cost of wells, quantity and quality of water, etc., have likewise proved of much value.

Another important class of people benefited are those interested in the development of mineral waters for bathing, sanitariums, and resorts, or for the purposes of bottling for table or medicinal uses. The depths, quantity, composition, and temperature are all most satisfactorily afforded by records supplemented by the analyses which are usually made soon after the well is completed and which, like the records, are often soon lost.

Records of adjacent wells may, in cases, be of great benefit, especially to owners in furnishing a check on statements as to the occurrence of water horizons, depth to rock, amount of casing, total depth of well, etc., all of which are sometimes misstated when contracts have been let for a specified sum per foot or which have been inaccurately reported because of failure to keep proper records. They also afford a basis of comparison as to conditions with more successful or less successful wells of the locality, and frequently give a clue to the cause of failure or of variations from the normal wells.

In many regions the surface wells gradually fail because of the deforesting of the land or its drainage by ditches, and it may become necessary to sink deep into the rock for a permanent supply. All rocks do not yield water, while in some yielding abundant supplies the water carries too much mineral matter for ordinary use. It is in such regions that records, affording a basis for predicting results, are of special value.

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### IMPORTANCE OF RECORDS TO GEOLOGISTS.

To the geologist records are of value from both the practical and the scientific standpoints. Problems are submitted almost daily by drillers and by present or prospective well owners in regard to the occurrence of oil, gas, or water. Where he can visit the field he can, as already indicated, work out the general features of structure and character and thickness of beds, and can make certain generalizations as to the occurrence of water and in some cases of oil and gas; but he can not give more precise information without a knowledge of the changes which the beds undergo beneath the surface, and these are best afforded by well sections.

The occurrence of oil and gas is shown, as accurate investigation proceeds, to be more and more dependent upon structure, which term is here used in a broad sense to include both the attitude of the rocks and the changes in extent, thickness, or texture which they may undergo from point to point, and the same holds to an even greater extent in regard to artesian waters. Combining well records with surface observations, the geologist is able to locate the anticlines, synclines, flats, etc., so important in their bearing on the occurrence of oil and gas, to determine similar structures governing the occurrence of artesian waters and regulating their head, to predict the character of the material to be penetrated, to fix the depth of the producing horizon, and in the case of water to estimate the approximate volume to be obtained.

From the scientific standpoint records and samples, especially where the latter include fossils, aid the geologist to a better understanding of the age and succession of the rocks, assist him in the correlation of identical or equivalent beds in remote localities, and enable him to work out the details of structure and history, all of which furnish a basis for conclusions which are of much benefit to the driller or well owner.

## WORK OF COLLECTING WELL RECORDS AND SAMPLES.

### ORGANIZATION.

#### EARLY COLLECTION OF RECORDS.

Ever since the organization of the Survey the collection of records as an aid to the study of geology has formed an incidental part of the work of the geologist in the field, but since the beginning of the precise stratigraphic and structural work of recent years the collection of records has become an important part of the Survey's work in certain regions. The vast majority of wells, especially in Pennsylvania, were sunk a number of years ago, but fortunately many records have been preserved. These were carefully collected by the geologists in the individual localities.

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## PROPOSED SECTION OF OIL AND GAS (1902).

The collection of records finally became so important that it was thought that a section, organized for the purpose of collecting them in connection with a study of the oil and gas fields, might be organized to advantage, and an outline plan for such a section was, at the request of Mr. M. R. Campbell, submitted to the geologist in charge of geology April 28, 1902, by the present writer. The following is an extract from this plan:

In the prosecution of the work of areal mapping, and in the determination of the structure of the areas surveyed by Mr. [M. R.] Campbell and members of his party in Pennsylvania and Indiana, it has become apparent that great importance is to be attached to the information which may be derived from the deep borings for oil and gas.

As has been pointed out by Mr. Campbell, it is generally only in increased details of outcrop, made possible by accurate topographic maps, and more especially in the greater refinement in structural details, that improvement has been made upon the detailed work of the earlier surveys in the region mentioned. Engineers, coal operators, and oil and gas men with whom the geologists have come in contact and who have learned of the nature of the structural work which is now being undertaken, have almost invariably shown a marked interest in what is being accomplished and have fully appreciated its value to them as practical men.

Already many errors, some of them very grave, have been found in the structural work of the Second Survey of Pennsylvania. Supposedly continuous folds have been found in reality to consist of a series of short disconnected ellipsoid domes and canoe-shaped troughs, and marked by frequent irregularities and by noticeable offsets at their terminations. Others have been shown to vary at angles as high as 60° or more from the positions previously determined, and, in fact, everywhere abound in unsuspected relations. The once famous oil fields west and northwest of Bradys Bend on the Allegheny River have previously been thought to have no relation to structure, but have now been proved to have a very close and definite relation to it, a fact that should be of great value in the drilling for the Speechley oil sand which is now going on, and in the drilling of gas wells, which, following the recent revival of activity, are fast becoming of great importance in this and other regions.

The determination of the minor but important details of structure is dependent (1) upon information afforded by mines, (2) upon observation and correlation of natural outcrops, and (3) upon information afforded by deep wells. The first is available only in synclines containing workable coals. The second is of little value in many localities because of the general absence of distinctive characteristics over broad areas and through considerable vertical ranges of the Devonian and Carboniferous rocks, not only in Pennsylvania and Indiana, but in many other of the areas where these rocks occur. In such regions the oil and gas wells have frequently furnished the only reliable data for the determination of the structural details.

The growing disposition on the part of the States to cooperate with the United States Geological Survey makes it somewhat probable that work similar to that now going on in Pennsylvania will at no very distant date be undertaken at other points, where presumably similar conditions will prevail and similar results be expected and required.

The great value of well records in his work in Pennsylvania was fully appreciated by Mr. Campbell, and considerable amounts of time were devoted both by him and by myself to the collection of such records. Some 1,500 were obtained in 1901. It has become apparent, however, that to carry out the collection of records to the

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extent desirable, and especially to properly file and catalogue them so as to be readily available, is impracticable with the present force. This, in addition to the advisability of collecting and publishing this information (which seems likely to be of considerable economic value), has led Mr. Campbell to suggest to me that I place before you the question as to the advisability of employing or assigning some geologist or other person who can devote the whole or a large part of his time to the work, and who should be given charge, under your supervision, of the work relating to oil and gas.

Some of the duties that might be expected to devolve, in whole or in part, upon an assistant geologist or geologist in charge of oil and gas are as follows:

1. To consult with other geologists and with hydrographers and topographers with the view of collecting and filing information relating to deep borings for oil and gas obtained by the various field parties of the Survey.

2. To obtain representative records and information as to structure of all pools as far as possible.

3. To collect and file samples of oil- and gas-bearing rocks, together with other characteristic beds encountered, as far as feasible.

4. To gather together published records and all available unpublished records as far as practicable, and to file them in the form of card catalogues which will be available to the members of the Survey at all times.

5. To prepare a bibliography of all oil and gas papers which have appeared in scientific publications and, as far as practicable, those which have appeared in trade journals up to and including 1900.

6. To keep a bibliographic catalogue of all oil and gas papers which have appeared since 1900 in both scientific and trade journals.

7. To review oil and gas periodicals and to keep records of developments and progress.

8. To keep a general index map showing the location of the oil and gas fields throughout the United States.

9. To keep State or county maps or topographic maps of the Survey, where available, to show the details of the various fields and pools of oil and gas.

10. To prepare geologic columnar sections for each pool as far as possible.

11. To prepare digests of structure for each pool as far as possible.

12. To keep a catalogue of all sands and their character and geologic positions as far as known.

13. To prepare correlation tables of the various sands where the information is available.

14. To visit new fields and investigate the geology and determine the structure, running levels where necessary.

15. To visit, collect records, and prepare reports on the oil and gas in quadrangles and districts where it is not practicable for the geologist in charge to give his personal attention to the problem.

16. To furnish other geologists with all information as to stratigraphy, structure, etc., which is afforded by the samples and by the records and other information on file.

17. To answer inquiries of operators, etc., regarding structure and other points relating to oil and gas as far as possible, without divulging confidential information.

18. To publish immediately in trade journals summaries of the geological knowledge of the regions of newly discovered pools.

19. To publish in Survey publications from time to time detailed reports of the development, structure, and general geology of new pools or the extensions of old pools.

20. To prepare statistics on production, etc., for the Mineral Resources, if required.

To summarize, the appointment or assignment of a geologist to take charge of the

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oil and gas problems would create a sort of "bureau of information" which would be of much value to both the operator and the geologist.

The gas production is greater now than at any time in the past, and the oil production is holding its ground fairly satisfactorily. It seems likely, therefore, that there will be steady demand for information for some time to come, and it is not unlikely that an "oil and gas division" could be made a division of some importance in the Survey.

## ORGANIZATION OF THE "WELL DIVISION."

The lack of available funds made it impossible to take up the plan as a part of the work of the geologic branch at that time, but in November of the same year a memorandum embodying a plan for a proposed "well division" was submitted to the Director by Mr. F. H. Newell. Under this plan it was proposed to organize in the hydrographic branch a division of work devoted to wells and ground waters, which should be under the charge of a geologist designated "chief of the well division," under whom would be two assistant chiefs, one for the eastern part of the country and the other for the western part, including the sixteen reclamation States and Territories. It was expected that each would spend at least four months of the year in the Washington office, so that one geologist would be constantly on duty to attend to administrative work and correspondence. It was proposed to give particular attention to a card catalogue of wells and to the compilation and filing of schedules relating to wells, which should include those drilled for oil and gas as well as for water. The catalogue and other data were to be available to the entire Survey, and the officers of the division were to supply information to drillers and others requesting it. In addition to the regular geologists, it was planned to have an assistant in each State to visit wells, study the stratigraphy, collect general information, and prepare detailed reports on the geology in its relation to the water resources, the results of which were to be published annually in progress reports, or as separate water-supply papers in the case of completed studies.

The memorandum of Mr. Newell was referred to Dr. C. W. Hayes, geologist in charge of geology, who, in a letter to the Director dated November 18, 1902, expressed his agreement with Mr. Newell as to the necessity of such an organized effort to systematically secure the records of wells being drilled for various purposes throughout the country, but questioned the desirability of placing one man in charge of the entire work. Instead, a recommendation was made that two geologists be employed, one to be placed in charge of the eastern section and the other in charge of the western. It was proposed that the general supervision of the work and of the scientific portions relating to water should rest with the hydrographic branch, while the portions relating to geology should be under the similar supervision of the geologic branch.

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The letter contained a recommendation that the present writer be assigned to the charge of the eastern section, which assignment was made by the Director on December 23. To Mr. N. H. Darton was assigned the charge of the western section.

## WORK OF THE DIVISION OF HYDROLOGY IN 1903.

The designation of "well division," later gave place to that of "division of hydrology," but without change of scope of work. Plans for collecting well records were taken up immediately on the organization of the division. As has been indicated, it was originally intended to include the collection of oil and gas records with those of water, but because of lack of available funds and proper assistance it was necessary to confine attention entirely to water. For use in connection with the collection of well data, forms for mailing to well owners and cards for filing the information were prepared. The form for mailing has been slightly modified from time to time. The form now used is as follows:

SIR: In its study of the water resources of the United States, which this Survey is making with the view of publishing the results for the benefit of the people, an attempt is being made to obtain important facts relating to wells, whether flowing or not. As it is impracticable on account of expense to visit all places, the endeavor is made to extend and complete the information by correspondence. If you will aid in this work by furnishing the data requested in the following list of questions your assistance will be much appreciated. If you can not supply all the data, kindly answer such of the questions as you can, a partial report being much better than none.

The following inquiry blank is on the same form with the above letter:

1. Well is in.....County. The nearest post-office is.....
   Distance of well from post-office..... (Miles.) Direction from post-office.....
   Locate by section if public-land surveys exist: Township....., Range.....,
   Section....., Quarter.....
   If in town, give street and number.....
2. Owner ..... Address.....
3. Driller ..... Address .....
4. Situation of well..... (Hill, slope, plain, valley.) Elevation is.....feet.....the (Above or below.)
   level of ..... (Sea, railroad station, lake, river.)
5. Type of well..... (Dug, driven, bored, or drilled.) Year completed..... Diameter at
   top..... At bottom .....
6. Depth of well..... Does it enter rock?..... If so, at what depth?.....
7. Depth to principal water bed..... Character of
   water bed ..... (Gravel, sand, clay, rock, etc. If rock, state kind.)
8. Were any other water beds or seams found?..... If so, give depth of each.....
9. Give sizes and lengths of casing.....

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10. Does water flow at surface without pumping?..... If so, at what height does it now flow?.....
Has it been tested to see how high it will rise?..... If so, to what height?..... What is its pressure?.....
If not flowing, how near surface does it stand when highest?.....
When lowest?.....
11. Is well pumped?..... If so, by what .....
(Suction, deep well, or force pump, steam, gasoline, air-lift, or windmill.)
12. Temperature of water at well mouth..... Month taken.....
Temperature at bottom .....
13. Natural yield, if flowing..... Maximum yield by pumping.....
(Gals. per min.) (Gals. per min.)
water is lowered.....feet by pumping.
(State number.)
14. Has supply decreased or increased?..... To what due?.....
15. Is flow or clearness of water affected by storms, winds, etc.?..... If so, describe .....
16. Quality of water—hard, soft, salty, alkaline, iron, or sulphur bearing.....
Cost of well..... Of pumps.....
17. Is water used for drinking?..... Washing?..... Cooking?.....
Stock?..... Manufacturing?..... Irrigation?.....
If for manufacturing uses, state nature..... If for irrigation, give crops .....
If used for public supply, give number of buildings and people supplied:
Buildings..... People.....
Is it sold?..... If so, for what purposes?.....
If used for purposes not mentioned, please name.....
18. Describe interesting peculiarities of well, if any, on back of this sheet.....
19. Give record of beds passed through, analysis of water, names of other well owners or drillers on back.
Name of person filling out blank .....

These or similar circulars were distributed in Maine, New Hampshire, Vermont, Rhode Island, Connecticut, New York, Georgia, Florida, Mississippi, Tennessee, Kentucky, Arkansas, Missouri, Iowa, Minnesota, Wisconsin, and Michigan, and a large number of records were obtained, of which about 2,750 were listed in Water-Supply and Irrigation Paper No. 102. The larger part of the records gave little information as to the strata penetrated, although a considerable number of detailed records were obtained from scattered localities and published in the paper mentioned. The circulars described are still largely used to obtain data relating to wells other than records of strata penetrated.

### PRESENT ORGANIZATION OF THE WORK.

In the summer of 1903 it became necessary, in order to make fine distinctions in glacial materials on Long Island, New York, where the geology and water resources were under investigation, to collect samples from the wells being drilled on the island. This work of collecting samples was in charge of Mr. A. C. Veatch. The will-

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ingness shown by operators and drillers to assist and the value of the material obtained suggested the organization of a similar system for the entire country.

Accordingly, during the fall of 1903, Mr. Veatch drew up an outline of a proposed system for collecting and preserving well samples, which was indorsed by the geologists interested in the keeping of records and samples, with the result that it was decided to take up the work as soon as circumstances should permit, which was at the beginning of the fiscal year 1904–5.

The plan outlined by Mr. Veatch for the collection of well records and samples contained many points in common with that for the proposed "oil and gas section," submitted by the present writer in 1902. (See pp. 28–39.) The principal points of difference are the inclusion of water wells in the present system and the exclusion of oil and gas data, except as they relate to stratigraphy and structure as shown by the well records. The items covered by paragraphs 1, 2, 3, 4, 7, 16, and 17 of the former plan are likewise covered by the present work, while it is hoped that in the future those mentioned in paragraphs 10, 11, and 14 will also be included.

As the plan originated in the division of hydrology the new work was assigned to it, about two-fifths of the expense being borne by the eastern section and the remainder shared equally by the western section of hydrology and the geologic branch. The oversight of the work rests with the chief of the eastern section, but its inauguration was placed in the hands of Mr. Veatch, assisted by Mr. E. F. Lines, by whom it was put into successful operation. On the relinquishment of the work by Mr. Veatch, who wished to take up more purely scientific problems, the prosecution devolved upon Mr. Lines, to whom much of the success of the work is due.

## RESULTS.

The results obtained during the six months in which the system for collecting records and samples has been in operation are very gratifying. The practical nature of the plan has appealed to drillers and others interested in wells and has resulted in many offers of cooperation. The plan has likewise been cordially received by the press and favorably commented upon editorially.

In the office the plan has likewise been shown to be eminently practical. The system outlined by Mr. Veatch has now been in operation long enough to thoroughly test its efficiency, and has proved to be simple in operation, economical as to labor, convenient to handle, and effective in its results. A few minor changes have been found desirable, but in all its main features the plan followed is substantially as originally formulated.

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The results of the work may be summarized as follows:

Approximate number of persons returning samples, 200.
Number of wells represented by complete sets of samples, 111.
Number of wells represented by incomplete sets of samples, 190.
Total number of samples received, 3,945.
Records received in Survey notebooks, 139.
Records received in other ways, 230.

The scientific results include detailed records from 111 wells. Of these nothing need be said, their character being indicated by the present report.

## METHODS OF WORK.

A number of States have, as a part of their work, undertaken a more or less systematic collection of deep-well records. The Second Geological Survey of Pennsylvania especially gave great attention to this feature, employing several men on the work of collecting and tabulating well records, of which several thousand were published. In some cases observers selected by the State survey were stationed at certain important wells to insure the collection of samples and the taking of accurate measurements. A great number of well records have also been independently collected by geologists throughout the country for the information they throw on stratigraphic and other problems, and a considerable number of them have been published, often constituting contributions of great importance to those interested in the occurrence of oil, gas, brines, and potable waters. The present system of the United States Geological Survey is believed to be more extensive and comprehensive than any previously put in operation for the collection of well records and samples, and it has been thought desirable to put on record a description of the plan, for the benefit of those persons or organizations who may desire to conduct similar work in the future.

It being manifestly impossible, because of the great expense involved, to place observers at the various wells, it was necessary to arrange for cooperation on the part of drillers throughout the country. This cooperation could in general be expected only when the drillers should be substantially benefited by the work, and consequently in the development of the plan this point was kept constantly in the foreground. Arrangements were made whereby such questions as the drillers should submit in regard to their work would be promptly attended to, and records interpreted or samples examined on request. In return the driller is requested to furnish written records of his wells and samples of materials penetrated, his assistance to be acknowledged in the reports on well records, issued annually.

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## GENERAL PLAN AND DETAILS OF WORK.

(FORMULATED BY A. C. VEATCH.)

The plan followed in the collection of well records and samples was developed by Mr. A. C. Veatch, assistant geologist, who also drew up the various forms used in correspondence, field, and office. The work may be summarized as follows:

First step is to obtain the names and addresses of drillers and well owners, who are informed of the advantages of saving samples and records and invited to cooperate. When a driller signifies his willingness to assist, he is supplied with notebooks for keeping the records, and small bags for shipping the samples through the mails free of cost. The receipt of all records or samples is acknowledged. If the original invitation to cooperate is not answered within a reasonable time, a second request is sent, which may be followed by others if necessary. An account is kept, by means of a card file, of letters and bags sent, and the records and samples are likewise systematically filed as received. At the end of each year, or oftener if the conditions demand, a report is to be prepared giving the names of persons cooperating, a summary of the wells reported, and complete records of the more important wells represented by samples or by detailed records.

### SOURCES OF ADDRESSES OF DRILLERS AND WELL OWNERS.

One of the first steps in the work was to secure the names of drillers or owners of wells in process of drilling. These were obtained from the following sources: (1) City directories, gazetteers, etc., (2) parties voluntarily offering to cooperate, (3) trade and engineering publications, (4) geologists and others in the field, (5) newspaper clippings.

The city directories and gazetteers of drillers furnished the largest number of addresses, but as all classes of drillers, including many local operators, are there included the percentage volunteering to assist was small. Perhaps the most effective aid was secured through voluntary offers of assistance from drillers in response to a press notice describing the work which the Survey is undertaking in the collection of samples and records and asking for cooperation. This was widely published, often with favorable editorial comment, in engineering, oil, and water journals and in newspapers. A large number of addresses of drillers and owners were also secured from advertisements for bids, news notes on water supplies, etc., in the engineering and trade journals. The journals now consulted are as follows: Engineering News, Fire and Water Engineering, American Magazine of Mining and Investment, Pacific Oil Reporter, Petroleum Gazette, Oil Investors Journal, and the semiweekly Oil City Derrick. A single issue of a weekly magazine may furnish as high as ten or more addresses, and the

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cooperation obtained through these addresses, especially through those obtained from advertisements for bids, is especially efficient. The newspapers throughout the country contain a vast amount of information relating to wells, but it has been found that this is not satisfactorily collected by the press-clipping bureaus, and at present little use can be made of it.

*Filing of clippings.*—The magazines are examined as received and clippings taken of advertisements for bids, news notes, etc. These, together with the clippings received through the press bureaus, are commonly pasted on a 4 by 6 inch card. At the top of this card is space for the name of the State, county, and town. If the clippings are long and require folding, an envelope attached to the face of the card, opening upward, is of much assistance in filing.

The clipping cards are marked with the name of the publication, and the volume, page, and date, after which they are filed by State, county, and locality. The clipping file gives not only addresses, but a comprehensive summary of drilling operations and allied subjects.

### PREPARATION OF MAILING LIST.

Each name and address of a driller or well owner is entered on a 4 by 6 inch card, which also serves as a stock card. In addition to the spaces for the name and address there are spaces for recording the position (owner, contractor, foreman, driller, etc.) of the person referred to, the dates on which circular letters inviting cooperation were sent, the addresses to which supplies are sent, the number of notebooks and bags furnished, and the dates on which they were forwarded. The form of this card is shown below.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Name, Position,

Permanent address, First circular sent,

Circulars sent.

| Date. | Address. | N. B. | Account of bags sent. |
|---|---|---|---|
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ARRANGEMENTS FOR COOPERATION.

When the addresses are first recorded on the cards, a letter inviting cooperation is sent. The character of the letter varies with the person to whom it is addressed, but one or the other of two forms is commonly used. These are given below, the first being sent to drillers and the second to well owners.

*Letter sent to drillers.*

SIR: The demand for information regarding wells has become so great that the United States Geological Survey has decided to issue a yearly publication giving briefly an account of the wells bored in the preceding year. This report is to be published as near the beginning of each year as practicable, and will be sent to all who apply for it. It will contain the names and addresses of persons doing well work, and will summarize the work done by them in the preceding year.

In order that no portion of your work may be overlooked in this report, you are requested to inform this office from time to time of the progress of your work and to forward records and samples of the materials penetrated in your wells.

That the foreman of the outfit, or the person visiting the wells, may not be burdened with a great number of bulky bottles or cans and an ever-growing accumulation of samples, small canvas bags have been prepared (one of which is inclosed) in which samples may be transmitted through the mails without the payment of postage. As these samples can be mailed as often as the men visit the post-office, there is no danger that they will accumulate and become burdensome. For the keeping of a log a convenient pocket memorandum book has been prepared and will be sent with the sample bags.

In order to keep in touch with you and your foreman, a card like the inclosed will be mailed at stated intervals. This will not only serve as a reminder, but will save you some clerical labor.

This work should enlist your cooperation for the following reasons:

First. Your name and work will be kept before a class of readers interested in well drilling.

Second. Records of your work will be carefully filed in this office, and will be readily available to you at any time, so that in case your notes are lost they can be duplicated.

Third. You will aid materially in the study of the geological structure of the United States, a knowledge of which can not fail to benefit you as a well driller.

In some cases it will be necessary that the records should be regarded as confidential, and in these cases the information will be carefully guarded, and used only under the conditions which you stipulate.

I shall be glad to hear from you regarding this work and will be grateful to you for any suggestions.

*Letter sent to well owners.*

SIR: The Survey is making a systematic collection of well records and samples. Such data are of great assistance in the study of many of the problems which the Survey is called upon to investigate, and you are cordially invited to render assistance by sending to this office records and samples from the wells in which you are interested.

The results of this work, except in cases of confidential records, will appear in a yearly publication and in detailed reports of special areas, which will be prepared from time to time, copies of which will be sent to you.

If you will undertake to save samples, please sign and return the inclosed card, which requires no postage. A supply of canvas bags like the one inclosed will then

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be sent you, in order that the samples may be transmitted through the mails without the payment of postage.

In some cases it is necessary that records be regarded as confidential, and in these cases the information will be carefully guarded and used only under the conditions which you stipulate.

When the first letter inviting cooperation is sent out the date is entered on the card (p. 29). If a reply is not received in two weeks or a month, it is often desirable to send out a second letter. In order to keep track of this correspondence, projecting metal clips of different colors are used. Thus, if the first circular is sent out on January 1, and it is desired to send a second letter on January 15, the date January 1 is entered on the line opposite "circulars sent," while the clip is placed on the number 15 at the top of the card. As the cards are of uniform size and fit closely into the drawer, all the clips for a given date fall in a single line, and it is easy to select the cards for a particular date without handling those relating to any other date. To assist still further in handling the correspondence, clips of the following colors are used for the different classes of cooperators: Copper for persons such as foremen for large firms saving samples by order of employers or others; white for all other persons saving samples; green for owners not saving samples, and steel-blue for drillers not saving samples.

If a reply is not received to the first letter by the end of two weeks, a second letter is sent, which is commonly as follows:

*Second letter sent to drillers and well owners.*

SIR: In order that the collection of well samples being made by this office may be as complete as possible, one of the inclosed forms is sent at stated intervals to all persons interested in well drilling.

If you will save samples of well borings for the Geological Survey, please fill out this card, which requires no postage, and return it to this office, when a supply of canvas bags, which will carry the samples through the mail without the payment of postage, will be sent you.

The card should also be filled out if you need additional sample bags or if you are about to move your outfit to a new place.

If a reply to the second letter is not received, the same form is sent again after an interval varying with the individual circumstances. By repetition the letter serves to impress the importance of the work upon persons not responding to the first invitation, with the result that cooperation is sometimes finally secured. The same letter is also sent from time to time to persons saving samples, in order to keep in touch with them, to make sure that the work is not forgotten, and that the necessary supplies are ordered as required.

With the original letter inviting cooperation and with the second letter there are inclosed a sample of the bags used for shipping samples and a franked card on which the recipient can designate the number of notebooks and bags required.

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The sample bags are of light but strong canvas and measure 3½ by 5 inches. On them are printed the "penalty frank" and the Survey address. At the top is a string for securely tying in the contents before shipment.

When the card requesting supplies is received the supplies are immediately shipped, together with a notice of shipment.

### TAKING OF NOTES AND SAMPLES.

*Form of notebook used.*—As every effort has been made to assist the driller in keeping notes and saving samples, special notebooks as well as sample bags were devised.

On the front cover of the notebooks now in use[a] is the title, and on the back cover are printed a postal frank and the address of the Survey, so that the book may be returned by mail without wrapping. Experience has shown that the books become much less soiled than was anticipated, little trouble being encountered in this line.

The inside of the front cover contains the following simple directions, prepared by Mr. Veatch:

*Suggestions to drillers.*

1. Samples should be taken from each bed passed through, and never more than 20 feet apart, even in the same bed.
2. Samples from wells in sands and clays should not be washed, as washed samples of sandy clay show only clean sand and give a wrong idea of the character of the bed.
3. All oyster, clam, or other fossil shells should be placed in the bags with the dirt or sand in which they are found and marked with the depth from which obtained.
4. Samples should be dry before being mailed.
5. A blank label will be found in each bag. After it is filled out it should be folded once to protect the writing.
6. Bags should be tied securely and mailed. They require no postage.
7. In the first two or three samples sent in, the "Location" should be filled out with care; in the succeeding samples so much care need not be taken with location, but the rest of the card should be complete.
8. Note depth and thickness of all water-bearing layers.
9. Note under "Remarks" the quality of the water from each layer, as hard, soft, salty, alkaline, or sulphur bearing.
10. Note height to which water from each layer rises in well, and give flow in gallons per minute.
11. Make frequent use of the "Remarks" column to explain your notes.
12. If you leave the rig, send in your notebook with the name of your successor and a new book will be sent to him.
13. If you do not understand what is wanted, or desire information on any point, write to this office, using one of the envelopes sent with the first shipment of bags. They require no postage.
14. It sometimes happens that unauthorized persons represent themselves as members of the Survey. If you desire to know whether a man is connected with the Survey, ask for his identification card, which is signed by the Secretary of the Interior and the Director of the Geological Survey.

[a] A new edition to be used after January 1 varies in a number of unessential particulars from the form here described.

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Names of owners and drillers who furnish records and samples will appear in the annual publication of the Geological Survey on well borings.

The Survey desires to assist and cooperate with owners and drillers in every way possible, and will be glad to answer questions.

To assist the driller in identifying the rocks, in obtaining a correct understanding of simple geologic conditions, and in keeping more intelligent records, a few geologic notes and definitions of the more common types of rocks, based largely on notes by Mr. G. H. Eldridge, are printed on the inside of the back cover and on the page facing it, respectively. These are given below.

*Geologic notes.*

In a simple classification rocks may be grouped into three divisions: (1) Sedimentary, (2) metamorphic, and (3) igneous.

*Sedimentary rocks.*—Sedimentary rocks are formed of fragments worn from older rocks by the action of rain, wind, frost, etc. Such materials were carried by water or glaciers until deposited as beds of clay, sand, gravel, marl, etc. Other deposits consist largely of corals, or of shells, such as oysters and clams. When first deposited the materials are loose and unconsolidated, but they become gradually hardened and cemented together, especially when covered by later beds, and form solid rocks.

*Metamorphic rocks.*—Sedimentary rocks have frequently been subjected to heat and pressure, which has further hardened them, or even produced a crystalline texture. Sediments and igneous rocks so altered are known as metamorphic rocks. Mica-schist and marble are typical examples. They generally retain a bedded or foliated structure.

*Igneous rocks.*—Igneous rocks have come from the earth's interior in a molten state and have forced their way between other rocks or have overflowed as lava beds at the surface. They are nearly all more or less crystalline in texture.

*Resemblance of rocks of different ages.*—Rocks of the types indicated above occur the world over, those of one locality often being indistinguishable from those of another. Notwithstanding this, there may be a difference of thousands of years in age and a great variance in conditions of formation. It is not warrantable, therefore, to say that because a rock in California has the same composition as an oil-bearing rock in Ohio it is of the same age and will yield petroleum.

*Fossils.*—In sedimentary rocks remains of animals and plants are often found. These generally consist of portions or impressions of shells, skeletons, or leaves, and are known as fossils. A bed can frequently be recognized and its age determined by fossils. It is of great importance that all fossils be saved.

*Definition of a formation.*—A rock or succession of rocks possessing uniformity of character throughout a considerable area is termed a formation, and is given a name, such as Trenton limestone, etc. The importance of identifying these is great, and their identification will be much facilitated by the preservation of samples.

*Structure.*—When deposited, sedimentary beds are nearly horizontal. Subsequently they have often been thrown into inclined positions or bent into wave-like folds, the arches of which are known as *anticlines* and the troughs as *synclines*. When the beds are further disturbed they may become broken and the different parts displaced or *faulted* from their original position. The slope of the beds is known as the *dip*, and the direction in which they extend or would outcrop on a horizontal surface is known as the *strike*. The directions of strikes and dips are of importance in studying the occurrence of water and oil, and should be recorded whenever possible.



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## The definitions of rocks are as follows:

In order to assist the driller in keeping records, brief definitions of the more common rock terms are given below.

### UNCONSOLIDATED DEPOSITS.

*Soil and subsoil.*—The weathered upper portions of any rocks.

*Till.*—An irregular mixture of clay, sand, and bowlders deposited by glaciers.

*Alluvium.*—Sand, clay, etc., deposited by streams.

*Gravel, sand, and clay.*—Made up respectively of pebbles, sand grains, and finer particles.

*Chalk.*—A soft, white earthy substance made up of fine particles of lime.

*Marl.*—A clayey substance containing much lime.

### SEDIMENTARY ROCKS.

Sedimentary rocks are made up of fragments of older rocks. The fragments or grains are usually rounded, a feature which helps to distinguish them from igneous rocks.

*Conglomerate.*—Consolidated gravel.

*Sandstone.*—A consolidated sand. It is said to be *massive* if there are few bedding planes, and *shaly* if it splits into plates.

*Quartzite.*—A sandstone in which the spaces between the grains have filled with a hard cement (silica), forming an excessively hard rock.

*Shale.*—Consolidated clay; a soft, fine-grained rock which tends to split into thin plates (often improperly called soapstone).

*Slate.*—Like shale, but harder; splits into thin plates which may or may not coincide with the bedding. The tendency to split is not often recognized in drilling. Example: Roofing slate.

*Limestone.*—Formed from consolidated marly beds, or from beds of coral, shellfish, etc. It is composed mainly of carbonate of lime, but often contains sand and other impurities, and is often very hard. It can be most readily detected by the bubbling which takes place when it is touched with muriatic acid.

*Flint, rock salt, gypsum, coal.*—These are too well known to require definition.

*Concretions.*—Hardened lump-like masses within the rock, and should not be confounded with real bowlders.

### METAMORPHIC AND IGNEOUS ROCKS.

These rocks are generally made up of angular crystals, often recognizable by their glistening faces, a feature which is not often possessed by the fragments of sedimentary rocks.

*Marble and dolomite.*—*Marble* is a crystalline limestone and gives the same reaction with acid as limestone, marl, and chalk. *Dolomite* resembles limestone, but the bubbling with acid takes place only when the acid is hot. In composition it differs from limestone and marble in that it contains carbonate of magnesium.

*Soapstone or talc.*—Fairly soft and greasy to the touch. It is seldom encountered in drilling, the substance called soapstone usually being a soft shale, although the name is sometimes incorrectly applied to clay or slate.

*Schist.*—A crystalline rock characterized by thin layers of mica or other mineral.

*Gneiss.*—A rock intermediate in character between schist and granite.

*Granite.*—A crystalline rock composed of quartz, feldspar, and other minerals.

*Trap.*—A very dark crystalline rock of igneous origin.

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The first page of the notebook is used for a general record of the well. It is as follows:

*Well record on first page of driller's notebook.*

Well is located.....miles in a.....direction from.....post-office, in the .....¼ of.....¼ of Sec.....Twp.....Range.....

Owner.....

Contractor.....

Drillers.....

Well began....., 190.; completed ....., 190.

Rig used—cable, rotary, jet, or.....

Diameter of well:.....inches from.....ft. to.....ft.; .....inches from.....ft. to.....ft.

Length of casing.....

Casing perforated or strainer inserted at.....ft.

Main water supply from .....ft.

Well pumps.....gals. per minute from depth of.....ft.

Well flows.....gals. per minute from depth of.....ft.

If flowing, what is the pressure?.....

Fill out for oil and gas wells.
- Pool or district.....
- Well No.....on.....farm.
- Amount of oil obtained.....
- Amount of gas obtained.....
- Name of sand.....

.....

.....

.....

Recorded by.....

Address .....

The notebook contains 7 double pages for the recording of data. It is an adaptation of a form used by Mr. M. R. Campbell for oil records, which in turn followed the general plan of the notebooks of the Second Geological Survey of Pennsylvania and of later surveys and corporations. On each double page are seven columns, headed as follows: "Sample No.," "Rock or material," "Color," "Hard or soft," "From—," "To—," "Remarks."

*Taking and forwarding samples.*—In taking, preparing, and shipping samples the suggestions in the notebooks are generally followed fairly closely. The samples are commonly taken every 10 feet, or at every change of material, dried on a board or otherwise,

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and then placed in the bags. With each sample is included a 2 by 3 inch label, on which the following data are given by the driller: Sample number, location, name of owner, driller, and person sending sample, and the depth at which the sample was obtained.

### EXAMINATION AND FILING OF SAMPLES.

*Transfer to bottles.*—When received at the office the samples are transferred to glass bottles. The bottles now in general use are approximately 2¾ inches long and three-fourths inch in diameter.

Glass jars, measuring 3 by 1¾ inches, with a tin cover screwing on the top, were originally used, but they were found to be larger than necessary in most cases, although they are convenient where fragments are blown out in shooting or where fossils or pebbles are brought up.

*Acknowledgment of samples.*—When the bags are opened the labels are examined and acknowledgment is made to the persons sending them.

### EXAMINATION OF SAMPLES AND FILING OF RECORDS.

Whenever a set of samples from a particular well is complete it may be taken from the temporary files and referred to a geologist for examination and identification. The data thus obtained, together with those afforded by the drillers' notebook, are then compiled on cards. At the top of these cards are spaces for the names of State, county, and town in which the sample was obtained, for the names of the owner and driller of the well and of the person sending the samples, and for the dates of opening and closing the account. Below this space for general information are seven columns, which contain the following headings: "Date," "No.," "Character of strata," "From—," "To –," "Drawer No.," "Date." If the record is long, supplementary cards are used. These are ruled as described above, but at the top there are spaces for only the names of the State, county, and town.

Data of economic value are recorded on a separate card. The various cards, together with clippings, notebooks, etc., relating to the same well are then fastened together by a clip and filed by locality.

### STORAGE OF SAMPLES.

*Importance of preservation of samples.*—Mr. A. C. Veatch urged the general preservation of samples, as descriptions even by the best geologists are seldom as satisfactory as the samples themselves. Because of advances in geologic science and of later and more precise data for discriminating the characters of underground beds, peculiarities which had been entirely overlooked or misinterpreted often become clear as a result of a later examination. Many facts of value,

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both to science and to the practical driller, would undoubtedly be lost if the samples were discarded as soon as examined. Of course, certain simple types of sandstones, shales, and limestones can be described with a considerable degree of accuracy, and such samples, together with duplicates from the same bed, can be discarded, but the present policy is to preserve everything that can possibly be of value.

*Labeling of sample bottles.*—When the samples are transferred to the bottles a label is made out from the field label which accompanies the sample. It is printed on gummed paper, so that it may be easily attached to the bottle, and on it are written the well and sample number, depth, date, location, and name of owner.

*Temporary files.*—The samples frequently come in one or two at a time, and it is generally desirable to postpone final examination until all those from the same well have been received. As received they are put into bottles, labeled, given well and sample numbers, and put into a case for temporary filing. The object of the temporary files is to afford storage for samples from miscellaneous wells until the sets from the individual wells are complete. The cases are built in units with smooth ends 40 inches long, 32½ inches high, 24 inches deep, and are provided with glass doors to shut out the dust. Each contains 14 drawers in 2 rows of 7 each. Each drawer is 15½ by 20½ inches, inside measurement, and is 2½ inches deep. The guides are so placed that a space of three-fourths of an inch is left between each drawer to allow for the projecting bottles. The drawers are further subdivided by pasteboard partitions, similar to those used in packing eggs, into 108 compartments, each one of which will hold four of the smaller bottles or one of the large jars. The maximum capacity is 432 bottles to a drawer, or about 5,000 to a case. As but few of the larger jars are used, the actual capacity is very near the maximum.

*Permanent storage of samples.*—After examination, or when a set is complete, if desired the samples are filed in permanent storage cases of the same type as the temporary files. The compactness of the storage system will be appreciated when it is pointed out that over 200,000 samples can be stored in a 10 by 15 foot room. The samples are filed by wells, which are numbered consecutively as the reports are received, the numbers being entered on the record cards, which are filed alphabetically under States and counties.

### RECORDS COLLECTED INDEPENDENTLY OF SAMPLES.

The most thoughtful drillers generally keep records of all wells drilled in new fields, but do not attempt to save samples, because of the labor involved in their handling and storage under ordinary conditions. Many of these records, which are often of much value in determining the geologic features of the region, have been, through the

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courtesy of drillers and well owners, presented to the Survey. To facilitate the copying and filing of these records the following blank is used. The size of the original is 8 by 10½ inches.

*Form used for obtaining well records.*

WELL RECORD.

Well is located.....miles in a .....direction from.....post-office in the.....¼ of.....¼ of sec....., twp....., range....., in the State of.....
Owner..... Contractor..... Driller.....
Well begun ....., 190..; completed....., 190..
Rig used: Cable, rotary, jet, or..... Total depth.....
Length of casing:.....ft. Diameter:....in. from.....ft. to.....ft.; ....in. from.....ft. to.....ft.
Water wells. Completed well develops the following water-bearing strata: From.....ft. to.....ft., from.....ft. to.....ft., from.....ft. to..... Main supply from.....ft. Completed well pumps.....gals. per min. Flows.....gals. per min. Pressure.....
Oil and gas. Pool or district..... Well No.....on.....farm. Well yields ..... Yield first 24 hours..... Initial pressure..... [Oil or gas.]
Records sent by..... Address.....

LOG OF WELL.

| From— | To— | Character of material. (State whether hard or soft, and give color.) | Remarks. (Note especially depths and thickness of all water-bearing strata, height to which water from each layer rises, quality of the water from each, and yield in gallons per minute.) |
|---|---|---|---|
| | | | |

CONFIDENTIAL RECORDS.

In many instances borings are put down at great expense for the simple purpose of testing for oil, gas, water, or mineral, or of determining the depth, character, and structure of coal, iron, or other mineral deposits. It can not be expected in such cases that the data obtained will be thrown open to others who have gone to no expense in the matter, but who would be only too glad to make use of the information for their own interest. It is almost universally recognized, however, that such information may be safely given to the United States Geological Survey, whose members are rigidly prohibited by law from having any personal or private interest in the lands or mineral wealth of the region under survey. Such informaton will, if desired, be regarded as strictly confidential, and a signed agreement by the Director to that effect will be given if requested. When confidential samples, records, or other information are received they are stamped "Confidential" and the material is securely cared for.

COOPERATION WITH STATE GEOLOGISTS.

In a number of States arrangements for cooperation have been made with State or local geologists. Two sorts of arrangements have been made. In Alabama, Iowa, Michigan, Minnesota, and West Virginia,

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the local geologists have furnished clippings, names of drillers, notices of wells, and other information or assistance. In Kentucky and Maryland, on the other hand, the State geologists act as the Survey's representatives, collecting the samples and records at the local offices and forwarding them to the Washington office.

### PUBLICATIONS.

It is intended to issue annually a report giving the result of the year's work. The present paper is the first of the series and represents the material received during the first six months of the operation of the work. Being the first report, it will differ somewhat from those which are expected to follow, in that an account of the organization and methods are incorporated in addition to the well data. The general plan is to present each year a list of persons cooperating in furnishing samples or records, a summary of the wells reported and the results, and detailed records of wells. It is believed that the success of the work depends largely on making the material immediately available to drillers, well owners, and geologists rather than holding it for complete reports, which can generally be prepared only after many years of work, during which the information would be relatively inaccessible to those outside the Survey. Detailed reports, however, afford comprehensive views of the fields treated, which are not afforded by isolated records, and are to be prepared as opportunity offers.

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# WELL RECORDS.

By E. F. LINES.

The records which follow were reported in 1904. A summary of all the records received is given in the tables, and detailed reports of the more important wells are given on page 78.

The sources of information are the records in drillers' notebooks and on record forms, letters, drafts of well sections, and samples of borings.

## SUMMARY OF WELL DRILLING REPORTED IN 1904.

*Abbreviations used in table.*

O, owner.
C, contractor.
D, driller.
M, miscellaneous sources of authority other than owner or driller.
L, Survey possesses a log.
S, Survey possesses samples.
— under "Height of water," distance of surface of water below the mouth of the well.
+ in same column, distance water will rise in an open pipe above the mouth of the well.
Under "Diameter" a series of figures indicates different diameters.



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*Summary of well drilling*

## ALABAMA.

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 1 | Covington | Andalusia | | | | Frank Sutter | |
| 2 | Madison | Hazelgreen, well No. 3 | | | | New York and Alabama Oil Co. | |
| 3 | Perry | Uniontown, 10 m. S. of | | | | G. B. Johnston | John I. Hawk |
| 4 | Tallapoosa | Alexander City, well No. 2. | 23 | 21 | 27 | Alexander City | J. O. Heflin & Co. |

## ARKANSAS.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5 | Arkansas | Dewitt | 4 S. | 3 W. | 33 | Mrs. Ella Johnson | Gunter Bros. |
| 6 | do | do | 5 S. | 3 W. | 4 | Harry Meritt | do |
| 7 | do | Stuttgart | | | | Edd Beity | do |
| 8 | do | Stuttgart, 15 m. SE. of | 4 | 4 | 12 | Fred Huffman | do |
| 9 | do | Stuttgart | | | | G. H. Kline | do |
| 10 | Pike | Bowen | | | | J. D. Hewitt | J. B. Dillon |

## CALIFORNIA.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 11 | Kern | Button Willow, 4 m. N. of. | 28 | 23 | 25 | C. B. Crawford | T. A. Pursell |
| 12 | do | Delano, 18 m. W. of | 25 | 22 | 16 | Frederick Cox | F. U. Pursell |
| a 13 | Monterey | Seaside | | | | B. N. Baker | |
| a 14 | San Diego | Point Loma | | | | Katherine Tingley | |
| 15 | San Francisco | San Francisco | | | | J. L. Flood | |
| 16 | do | do | | | | do | |
| 17 | Santa Cruz | Watsonville | | | | City | |
| 18 | Tulare | Waukena | | | | Waukena Water Co. | F. U. Pursell |

a See detailed record at end of table.

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*reported in 1904.*

## ALABAMA.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. Flow. | Yield per minute. Pump. | Year completed. | Kind of well. | Remarks. | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| ..... | O. | 420 | .... | 267 | ..... | ..... | ..... | 1904 | Water . | ..... | 1 |
| H. B. Conover.. | M. | 954 | .... | ..... | ..... | ..... | ..... | 1904 | Oil .... | No oil; yields some gas. (L. S.) | 2 |
| John I. Hawk .. | D. | 875 | 4-3 | 855 | — 40 | ..... | 10 | 1904 | Water . | Water stratum at 77 feet. (L. S.) | 3 |
| F. Osgood and J. Otis Heflin. | C. | 300 | 10 | 260 | —240 | ..... | 55 | 1904 | ..do .... | Water stratum at 80 feet. (L. S.) | 4 |

## ARKANSAS.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gunter Bros .... | C. | 96 | 2 | 95 | ..... | ..... | 8 | 1904 | Water . | Water stratum at 66 feet. | 5 |
| .....do ..... | C. | 101 | 2 | 98 | ..... | ..... | ..... | 1904 | ..do .... | Abundance of water. | 6 |
| .....do ..... | C. | 95 | .... | ..... | ..... | ..... | ..... | 1904 | ..do .... | ..... | 7 |
| .....do ..... | C. | 103 | 2 | 98 | ..... | ..... | 8 | 1904 | ..do .... | ..... | 8 |
| .....do ..... | C. | 100 | .... | 100 | ..... | ..... | ..... | 1904 | ..do .... | ..... | 9 |
| J. B. Dillon..... | C. | 170 | .... | ..... | ..... | ..... | ..... | 1904 | ..do .... | Strong flow. (L. S.) | 10 |

## CALIFORNIA.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T. A. Pursell.... | C. | 365 | 10 | 311<br>323<br>346 | ..... | ..... | ..... | 1904 | Water . | Water at 80, 109, 131, 167, 176, 229, 242, and 357 feet. (L. S.) | 11 |
| F. U. Pursell.... | C. | 828 | 11-10-8-7 | 755 | ..... | 1,077 | ..... | 1904 | ..do .... | Water strata between 484 feet and bottom of well. Sulphur and other minerals. | 12 |
| ..... | M. | 617 | .... | 610 | ..... | 30 | ..... | 1904 | ..do .... | Water-bearing beds at 270 and 540 feet. (L.) | 13 |
| ..... | O. | 400 | 6-5 | ..... | - 253 | ..... | 24 | 1901 | ..do .... | Elevation of mouth of well 256 feet. A. T. (L.) | 14 |
| A. L. Lowe ..... | M. | 136 | .... | ..... | ..... | ..... | ..... | 1904 | ..do .... | Abandoned. (L. S.) | 15 |
| .....do ..... | M. | 166 | .... | ..... | ..... | ..... | ..... | 1904 | ..do .... | .....do ..... | 16 |
| ..... | .... | 150 | 7 | ..... | ..... | ..... | ..... | ..... | ..do .... | Test well. Produces 400 gallons a minute. | 17 |
| F. U. Pursell ... | C. | 868 | 10 | 470 | ..... | 1,050 | ..... | 1903 | ..do .... | ..... | 18 |

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*Summary of well drilling*

## COLORADO.

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 19 | Denver | Denver | 35 | 68 W. | 20 | Dr. Albert A. Clough. | |
| 20 | Kiowa | Haswell | | | | Missouri Pacific Rwy. Co. | |
| 21 | do | Stuart | | | | do | |
| a22 | Otero | Lajunta | | | | Lajunta Oil and Gas Co. | |

## CONNECTICUT.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23 | Fairfield | Noroton | | | | Mrs. Anson Phelps Stokes. | Albert Lynch |
| 24 | do | do | | | | Wee Burn Land Co. | do |
| 25 | do | Stamford | | | | William Dashiell | do |
| 26 | Hartford | Farmington | | | | C. F. Fienemann | E. D. Hammond |
| 27 | do | do | | | | William S. Miles | do |
| 28 | do | do | | | | H. T. Stenson | do |
| 29 | do | do | | | | Gustav Wollenberg. | do |
| 30 | do | New Britain | | | | Town of New Britain. | do |
| 31 | New Haven | Meriden | | | | J. W. Britney | do |

## FLORIDA.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 32 | Franklin | Carrabelle | | | | Carrabelle Oil and Development Co. | W. F. Hamilton. |
| 33 | Polk | Bartow | | | | City of Bartow | do |
| 34 | St. John | St. Augustine | | | | Hotel Ponce de Leon. | |

a See detailed record at end of table.

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*reported in 1904*—Continued.

## COLORADO.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. Flow. | Yield per minute. Pump. | Year completed. | Kind of well. | Remarks. | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| T. Carlton Koogle. | M. | 260 | 4 | 230 | − 38 | ..... | ..... | 1902 | Water. | Yields soft water. | 19 |
| ..... | M. | 54 | 6¼ | ..... | − 45 | ..... | 25 | 1903 | ..do.... | Abandoned on account of decrease in yield. (L.) | 20 |
| ..... | M. | 49 | 10¼ | ..... | − 30 | ..... | 50 | 1902 | ..do.... | (L.)..... | 21 |
| ..... | M. | 1,703 | .... | ..... | ..... | ..... | ..... | ..... | Oil..... | (L. S.)..... | 22 |

## CONNECTICUT.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Albert Lynch.. | C. | 494 | 6–4¼ | 200 | − 12 | ..... | 4 | 1903 | Water. | Water-bearing beds at 300 and 350 feet. Water hard. | 23 |
| .....do..... | C. | 142 | 6 | 120 | − 16 | ..... | 20 | 1904 | ..do.... | Yields hard water. | 24 |
| George Northrop. | C. | 69 | 6 | 60 | ..... | ..... | 12 | 1904 | ..do.... | ..... | 25 |
| Delbert Howe.. | C. | 40 | 6 | 35 | ..... | ..... | ..... | 1904 | ..do.... | Pumps from 20 to 30 gallons per minute. (L.) | 26 |
| .....do..... | C. | 50 | 6 | 50 | ..... | ..... | 25 | 1904 | ..do.... | ..... | 27 |
| .....do..... | C. | 37 | 6 | ..... | ..... | ..... | 50 | 1904 | ..do.... | (L.)..... | 28 |
| .....do..... | C. | 118 | 6 | 108 | − 40 | ..... | 10 | 1904 | ..do.... | (L. S.)..... | 29 |
| .....do..... | C. | 167 | 6 | ..... | ..... | ..... | 2 | 1904 | ..do.... | Water at 75 and 155 feet. (L. S.) | 30 |
| .....do..... | C. | 65 | 6 | ..... | ..... | ..... | 10 | 1904 | ..do.... | Water at 40, 50, and 60 feet. (L.) | 31 |

## FLORIDA.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| W. F. Hamilton. | M. | 265 | .... | ..... | ..... | ..... | ..... | 1904 | Oil .... | Drilling suspended. (L. S.) | 32 |
| .....do..... | M. | 725 | .... | ..... | ..... | ..... | ..... | 1904 | Water. | (L. S.)..... | 33 |
| ..... | M. | 1,278 | .... | ..... | ..... | ..... | ..... | ..... | ..do.... | "Flagler Well." Flow at 468, 1,110, and 1,200 feet, latter "milky with lime." Flow also at 1,225 feet. (L.) | 34 |

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*Summary of well drilling*

**GEORGIA.**

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 35 | Berrien | Tifton | | | | H. H. Tift | M. H. Junard |
| 36 | Burke | Midville | | | | Allen W. Jones | W. H. Brown |
| 37 | Lee | Smithville | | | | City | |
| 38 | Walker | Chickamauga Park | | | | U. S. Government | |
| 39 | do | do | | | | do | |

**IDAHO.**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 40 | Fremont | Dubois | | | | San Pedro, Los Angeles and Salt Lake Rwy. Co. | L. J. Craig |

**ILLINOIS.**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 41 | Adams | Payson | | | | Jos. Scarborough | A. J. Clark |
| a42 | Boone | Belvidere | | | | Chicago and Northwestern Rwy. | L. Wilson Well Co. |
| 43 | Clark | Dave Lee farm | | | | Hoblitzell & Co. | |
| 44 | do | John Newlin farm | | | | do | |
| 45 | do | Phillips farm | | | | do | |
| a46 | Dupage | Naperville | | | | Naperville water Works. | L. Wilson Well Co. |
| a47 | Henry | Kewanee | 15 N. | | 32 | Kewanee Boiler Co. | J. P. Miller Artesian Well Co. |
| 48 | Lake | Libertyville | | | | | W. J. Miller's Sons. |
| 49 | do | Russell, 5 m. SW. of | 46 | 11 | 18 | Wilson King | W. M. Bolles |
| 50 | do | Russell | 46 | 11 | 22 | Estate of George Shea. | do |
| 51 | do | Waukegan | 45 | 11 | 1 | W. H. Finch | do |
| a52 | Lasalle | Streator | | | | Streator Bottle and Glass Works. | L. Wilson Well Co. |

a See detailed record at end of table.

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*reported in 1904*—Continued.

## GEORGIA.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. Flow. | Yield per minute. Pump. | Year completed. | Kind of well. | Remarks. | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| ..... | M. | 368 | 8 | 330 | −125 | ..... | 150 | 1901 | Water. | Hard; some sulphur. Temperature 73°. | 35 |
| ..... | O. | 750 | 5 | 700 | + 47 | 75 | ..... | 1901 | ..do.... | Hard; iron and sulphur. Water-bearing beds at 200, 300, and 450 feet. Temperature 68°. | 36 |
| O. L. Herrington | M. | 900 | 4–3 | ..... | + 18 to + 24 | 35 | ..... | 1890 | ..do.... | Soft. Water-bearing beds at 350 to 400 feet. Temperature 73°. | 37 |
| ..... | M. | 306 | 6 | 305 | − 25 | ..... | 106 | 1904 | ..do.... | Hard. Water at 110 and 290 feet. In dry season water falls to −100 feet. | 38 |
| ..... | M. | 306 | 10 | 305 | − 25 | ..... | 183 | 1904 | ..do.... | This well is 10 feet from one above; pumping one lowers the other correspondingly. | 39 |

## IDAHO.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ..... | C. | 615 | .... | ..... | ..... | ..... | 50 | 1903 | Water. | Water-bearing beds began at 375 feet. | 40 |

## ILLINOIS.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ..... | C. | 1,542 | 5¼–4¼ | 167 | −150 | ..... | 13 | 1904 | Water. | Fresh water from 167 to 1,000 feet, brine at 800 and 1,400 feet. | 41 |
| H. W. Hambrecht; H. Hemhoff. | D. | 1,231 | 10–8–6¼ | ..... | −20 | ..... | 180 | 1903 | ..do.... | Water-bearing beds at 574, 834, 1,070, and 1,231 feet. (L.) | a42 |
| J. N. Schell..... | O. | 360 | .... | ..... | ..... | ..... | ..... | 1904 | Oil..... | Oil at 360 feet..... | 43 |
| .....do..... | O. | 354 | .... | ..... | ..... | ..... | ..... | 1904 | ..do.... | Oil at 354 feet..... | 44 |
| .....do..... | O. | 385 | .... | ..... | ..... | ..... | ..... | 1904 | ..do.... | Oil at 385 feet..... | 45 |
| H. W. Hambrecht; H. Hemhoff. | D. | 1,425 | 12–10–8–6¼ | ..... | ..... | ..... | 140 | 1904 | Water. | Water-bearing beds at 792 and 1,425 feet. (L.) | 46 |
| L. Nichols; Wm. Trentlage. | D. | 1,073 | 12–10¼–8¼–6 | 954 to 1,073 | −350 | ..... | 80 | 1904 | ..do.... | Coal, 3 feet, at 187 feet; water at 415 feet. (L. S.) | 47 |
| ..... | C. | 179 | .... | ..... | ..... | ..... | ..... | ..... | ..do.... | Water-bearing beds at 11 and 45 feet. | 48 |
| W. M. Bolles.... | C. | 255 | 4¼ | 255 | ..... | ..... | 25 | 1904 | ..do.... | Water stratum at 150 feet. | 49 |
| .....do..... | C. | 175 | 4 | 175 | −12 | ..... | 20 | 1904 | ..do.... | Soft; sulphurous. (L. S.) | 50 |
| .....do..... | C. | 205 | 4 | 205 | −59 | ..... | 18 | 1904 | ..do.... | (L. S.) ..... | 51 |
| H. W. Hambrecht; H. Hemhoff. | D. | 1,115 | 8–6 | ..... | ..... | ..... | 130 | 1902 | ..do.... | Water-bearing beds at 596, 706, 834, 1,066, and 1,096 feet. (L.) | a52 |

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*Summary of well drilling*

ILLINOIS—Continued.

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 53 | Lasalle | Streator | | | | Streator Clay Manufacturing Co. | L. Wilson Well Co. |
| 54 | McHenry | Hebron | | | | Village of Hebron | W. J. Miller's Sons. |
| 55 | do | Richmond | 46 | 8 | 9 | L. B. Covell | do |
| 56 | do | do | 46 | 8 | 9 | F. McConnell | do |
| 57 | Sangamon | Springfield, 4½ m. N. of. | 16 N. | 5 W. | 10 | City | |
| 58 | do | do | | do | | do | |
| 59 | do | do | | do | | do | |
| 60 | Will | Crete | | | | C. and E. I. Rwy. Co. | |

INDIANA.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 61 | Dekalb | Garrett | | | | Baltimore and Ohio Rwy. Co. | Harmon Water Supply Co. |
| a62 | Delaware | Albany. Whitehair farm, well No. 1. | | | 24 | Brewster Oil Co. | St. Marys Drilling Co. |
| 63 | do | Muncie, 4 m. S. of | | | | Eureka Oil Co | |
| a64 | Jay | Redkey. Hoppis heirs farm, well No. 5. | 12 | E. | 24 | Dunkirkand Redkey Oil-Gas Co. | O. O. McCormic. |

INDIAN TERRITORY.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 65 | Cherokee Nation. | Bartlesville | | | | | |
| 66 | Osage Nation | Pawhuska | | | | | |

IOWA.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 67 | Bremer | Frederika | | | | Pioneer Prospecting Oil Co. | L. Wilson Well Co. |
| c68 | Cedar | Tipton | | | | City | |
| a69 | Cherokee | Cherokee | 92 | 40 | 28 | Cherokee State Hospital. | |
| a70 | Des Moines | Burlington | | | | Iowa Soap Co | R. J. Johnston |
| a71 | Scott | Davenport | | | | Independent Malting Co. | L. Wilson Well Co. |
| 72 | Woodbury | Sioux City, 3 m. NW, of. | | | | John Bushar | |

a See detailed record at end of table.
c See detailed record in report of Iowa Geological Survey, Vol. III, p. 197.

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*reported in 1904*—Continued.

ILLINOIS—Continued.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. Flow. | Yield per minute. Pump. | Year completed. | Kind of well. | Remarks. | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| H. W. Hambrecht; H. Hemhoff. | D. | 773 | 9–7 | ..... | ..... | ..... | 94 | 1903 | Water. | Coal at 223 feet; fire clay at 236 feet. This clay used for making tile. (L.) | 53 |
| ..... | C. | 269 | .... | 258 | −61 | ..... | 80 | ..... | ..do.... | Water-bearing stratum 60 to 148 feet. Water muddy. (L.) | 54 |
| L. C. and W. E. Trow. | D. | 84 | 5 | 84 | −38 | ..... | 12 | 1904 | ..do.... | (L. S.) ..... | 55 |
| .....do..... | D. | 92 | 5 | 92 | ..... | ..... | 12 | 1904 | ..do.... | (L. S.) ..... | 56 |
| ..... | M. | 46 | 10 | 33 | −11 | ..... | 350 | 1904 | ..do.... | (L. S.) ..... | 57 |
| ..... | M. | 45 | .... | 30 | ..... | ..... | ..... | 1904 | ..do.... | The 3 wells are 100 feet apart. (L. S.) | 58 |
| ..... | M. | 49 | .... | 35 | ..... | ..... | ..... | 1904 | ..do.... | (L. S.) ..... | 59 |
| ..... | M. | 275 | 8 | 275 | −25 | ..... | ..... | 1904 | ..do.... | Hard water at 200 feet. | 60 |

INDIANA.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A. D. Harmon.. | C. | 266 | 10 | 219 to 266 | ..... | ..... | 190 | 1904 | Water. | (L. S.)..... | 61 |
| Wm. Walters; Wm. Jamison. | D. | 1,262 | 8–6¼ | ..... | ..... | ..... | ..... | 1904 | Oil .... | Small amount of oil. (L. S.) | 62 |
| H. J. Hughes... | M. | 1,243 | .... | ..... | ..... | ..... | ..... | 1904 | ..do.... | ..... | 63 |
| Harry Albert; Geo. Albert. | M. | 1,385 | 8–6¼ 2 | 1,380 | ..... | ..... | *b* 5 | 1904 | ..do.... | Gas at 960 feet. (L. S.) | 64 |

INDIAN TERRITORY.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ..... | M. | 1,700 | .... | ..... | ..... | ..... | ..... | ..... | ..... | Oil at 1,286 feet. (L.) | 65 |
| ..... | M. | 2,000 | .... | ..... | ..... | ..... | ..... | ..... | ..... | Water at 1,145 feet. Gas pressure at 2,000 feet prevented further drilling. (L.) | 66 |

IOWA.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| H. W. Hambrecht, H. Hemhoff. | D. | 1,025 | 8–6¼ | ..... | −4 | ..... | 148 | 1902 | Water. | Water-bearing beds at 367, 717, and 883 feet. Well drilled for oil. (L.) | 67 |
| W. N. Treichler. | M. | 2,699 | .... | ..... | ..... | 50 | ..... | ..... | ..do.... | (L. S.) ..... | 68 |
| O. G. Wilson.... | M. | 1,120 | 12–9 | 1,120 | −206 | ..... | 7 | 1902 | ..do.... | Water-bearing beds at 225, 375, 405, 475, and 535 feet. Temperature 60°. Water hard. (L.) | 69 |
| R. J. Johnston.. | C. | 507 | 5¾ | 435 | ..... | 45 | ..... | 1904 | ..do.... | (L. S.) ..... | 70 |
| H. W. Hambrecht. H. Hemhoff..... | D. | 1,300 | 10–8 | 1,050 | ..... | 310 | ..... | 1904 | ..do.... | Water began to flow at depth of 996 feet. (L.) | 71 |
| Jace Carter..... | M. | 98 | .... | 90 | −50 | ..... | ..... | 1904 | ..do.... | (L. S.) ..... | 72 |

*b* Barrels a day.



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*Summary of well drilling*

## KANSAS.

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 73 | Allen | Laharpe | | | | | |
| 74 | Barton | Hoisington | | | | Missouri Pacific Rwy. Co. | |
| 75 | Butler | Rosalia | | | | | |
| 76 | Chautauqua | Hale. J. W. Darbro farm, well No. 1. | 32 | 12 | 13 | Darbro Oil Co | C. F. Noble |
| 77 | do | Hewins | 35 | 9 | 12 | Sterling Oil and Gas Co. | Alexander Bros. & Stauffer. |
| a78 | Greeley | Horace | | | | Missouri Pacific Rwy. Co. | |
| 79 | Greenwood | Eureka | | | | | |
| a80 | do | Neal. Robb farm, well No. 3. | 25 | 12 | | Raff & Gammon | Kennedy & Son. |
| 81 | do | Neal | | | | | |
| 82 | Montgomery | Independence. (Heckart No. 1). | 34 | 15 | 1 | Yoke & Brown | Patton & Wolford. |
| a83 | do | Independence. (Logan No. 1). | 33 | 15 | 27 | do | do |
| a84 | Neosho | Chanute. S. Smith farm, well No. 22. | 27 | 18 | 10 | I. N. Knapp | |
| 85 | do | Rollin (near) | 28 | 19 E. | 9 | Shaw farmers | |
| 86 | Pottawatomie | Onaga | 7 | 11 | 11 | | Bennett & Robbins. |
| 87 | Reno | Haven, 6 m. S. of | 26 | 4 | 6 | J. F. Eabling | E. A. Roberson |
| 88 | Rush | Bison | | | | Missouri Pacific Rwy. Co. | |
| 89 | do | McCracken | | | | do | |
| 90 | Sedgwick | Andale | 26 | 3 W. | 8 | M. Lill | E. A. Roberson |
| 91 | Woodson | Toronto | | | | | |

## KENTUCKY.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 92 | Warren | Bowling Green | | | | | |
| 93 | do | Bowling Green, 6 m. NW. of. | | | | Warren Petroleum Co. | |

a See detailed record at end of table.

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*reported in 1904*—Continued.

## KANSAS.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. Flow. | Yield per minute. Pump. | Year completed. | Kind of well. | Remarks. | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| ..... | M. | 1,050 | .... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 73 |
| ..... | M. | 200 | 6¼–5¼–5¼ | 184 | ..... | ..... | ..... | 1900 | Water. | (L.) ..... | 74 |
| ..... | M. | 2,062 | .... | ..... | ..... | ..... | ..... | ..... | Oil..... | Salt water at 733 and 1,350 feet. Water at 1,710 feet. Drilling suspended. | 75 |
| W. B. Frost; Lee McClung. | M. | 1,106 | 10–8¼–6¼ | ..... | ..... | ..... | ..... | 1904 | ..do .... | Salt water at 365 and 800 feet. Very little oil. | 76 |
| ..... | M. | 1,479 | 8¼–6¼–4¼ | ..... | ..... | ..... | ..... | ..... | ..do .... | Salt water at 510, 775, and 1,060 feet. Pay sand 1446–1474. (L.) | 77 |
| ..... | M. | 1,370 | 10 | 1,325 | −830 | ..... | 30 | 1901 | Water. | Water at 825 and 1,325 feet. Well abandoned. (L.) | 78 |
| ..... | M. | 1,255 | .... | ..... | ..... | ..... | ..... | ..... | ..... | Brine at 499 feet. | 79 |
| ..... | O. | 940 | 10–8¼ | ..... | ..... | ..... | ..... | 1904 | Oil..... | Water-stratum at 882 feet. (L.) | 80 |
| ..... | M. | 875 | .... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 81 |
| C. A. Williams; D. Hurst. | O. | 1,041 | 8¼–3 | ..... | ..... | ..... | ..... | 1904 | Gas.... | Yield 11,000,000 feet first 24 hours. (L.) | 82 |
| C. A. Williams.. | O. | 1,160 | 8¼–6¼ | ..... | ..... | ..... | ..... | 1904 | ..do .... | Water-bearing beds at 275, 640, and 895 feet. Yield 18,000,000 feet first 24 hours. (L.) | 83 |
| Roy Bair..... | M. | 752 | 5 | ..... | ..... | ..... | b5 | 1904 | Oil .... | Water at 30, 128, 521 feet. Brine at 385 feet. Oil at 720, 724, 728 feet. (L. S.) | 84 |
| ..... | M. | 652 | .... | 640 | ..... | ..... | b5 | 1904 | ..do .... | The oil grades 32°. (L.) | 85 |
| Bennett & Robbins. | C. | 602 | 3–2 | 540 | ..... | 5 | ..... | 1904 | ..... | Gas and flowing water 533 to 559 feet. (L. S.) | 86 |
| E. A. Roberson.. | C. | 39 | 12–5 | 39 | ..... | ..... | 52 | 1904 | Water. | (L. S.) ..... | 87 |
| ..... | M. | 294 | 8¼ | 282 | −55 | ..... | 90 | ..... | ..do .... | (L.) ..... | 88 |
| ..... | M. | 558 | 8¼–6¼ | 278 | ..... | ..... | 20 | 1901 | ..do .... | Water at 278 and 382 feet. Salty. (L.) | 89 |
| E. A. Roberson.. | C. | 52 | 10–6 | 50 | ..... | ..... | 30 | 1904 | ..do .... | Water at 30 feet. (L.) | 90 |
| ..... | M. | 1,140 | .... | ..... | ..... | ..... | ..... | ..... | ..... | Oil at bottom..... | 91 |

## KENTUCKY.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ..... | M. | 1,300 | .... | ..... | ..... | ..... | ..... | ..... | Oil .... | (S.) ..... | 92 |
| ..... | M. | 600 | .... | ..... | ..... | ..... | ..... | ..... | ..do .... | ..... | 93 |

b Barrels a day.

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*Summary of well drilling*

## LOUISIANA.

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 94 | Calcasieu | Edgerley | 10 | 11 | 22 | D. C. Brown | V. Wainright |
| 95 | do | Calcasieu | | | | Louisiana Oil Co. | Oscar Shanks |
| 96 | Rapides | Pineville | | | | State of Louisiana | do |
| 97 | Vermilion | Gueydan, 5 m. SW. of | 12 | 2 | 15 | A. B. Wilkinson | V. Wainright |

## MAINE.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 98 | Androscoggin | Lisbon Falls, 16 m. W. of. | | | | Worombo Woolen Mills. | Andrew S. Merrill. |
| 99 | Oxford | Rumford Falls | | | | Rumford Falls Light and Water Co. | Chas. Ray |
| 100 | Sagadahoc | Small Point | | | | Geo. O. Curtis | Smith & Thayer Co. |

## MASSACHUSETTS.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 101 | Hampden | East Longmeadow | | | | Frank Bane | F. A. Champlin |
| 102 | do | Springfield | | | | Andrew Kewic | do |
| 103 | do | Springfield, 4 m. N. of | | | | E. Perkins | do |
| 104 | do | do | | | | Thomas Webb | do |
| 105 | Worcester | North Grafton | | | | A. W. Baker | G. W. Patterson |
| 106 | do | Shrewsbury | | | | J. E. Dufresne | do |
| 107 | do | Worcester | | | | M. H. Cowden | do |
| 108 | do | do | | | | Mary E. Stevens | do |

## MICHIGAN.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 109 | Berrien | Benton Harbor | | | | Saltzman Mineral Bath Co. | Cartwright & Sherry. |
| 110 | Hillsdale | Prattville | | | | Henry Fickley | F. Howard |
| 111 | Iosco | East Tawas | | | | Michigan Pipe Co. | |
| 112 | Kent | Grand Rapids (Greenwood Cemetery). | | | | City of Grand Rapids. | O. L. Taylor & Son. |
| 113 | Luce | Newberry | | | | Superior Chemical Co. | Jas. Kinney, jr. |
| 114 | Mason | Fountain | | | | Martin H. Foster | |
| 115 | Oakland | Holly | | | | City of Holly | |
| 116 | Ontonagon | | 48 | 39 | 7 | Leo M. Geismar | |
| 117 | Wexford | Bagnall | 23 | 12 W. | 4 | | Lewis Maule |

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*reported in 1904*—Continued.

## LOUISIANA.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. Flow. | Yield per minute. Pump. | Year completed. | Kind of well. | Remarks | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| V. Wainright... | C. | 535 | 10 | 390 | 0 | 225 | 1,800 | 1904 | Water. | (L. S.)..... | 94 |
| Oscar Shanks... | C. | 2,200 | .... | 1,005 | ..... | ..... | 250 | 1901 | ..... | Well yields very warm, salty water. (L. S.) | 95 |
| .....do..... | C. | 428 | .... | ..... | ..... | ..... | ..... | 1904 | ..... | (L. S.)..... | 96 |
| V. Wainright... | O. | 280 | 12 | 150 | - 5 | ..... | ..... | 1904 | Water. | Temperature 60°. Water hard. | 97 |

## MAINE.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C. E. Shute..... | D. | 215 | 6¼ | 63 | ..... | ..... | 35 | 1904 | Water. | Hard water at 23 and 75 feet. Temperature 54°. (L. S.) | 98 |
| John White; Walter Follett. | M. | 60 | 2½ | 20 | ..... | ..... | 25 | 1904 | ..do.... | (L. S.)..... | 99 |
| J. J. McDonald.. | D. | 100 | 6 | 79 | ..... | ..... | 2 | 1904 | ..do.... | ..... | 100 |

## MASSACHUSETTS.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| James Egan.... | D. | 75 | 6 | 75 | ..... | ..... | 2 | 1904 | Water. | ..... | 101 |
| .....do..... | D. | 275 | 6–4¼ | 250 | ..... | ..... | 20 | 1904 | ..do.... | (L. S.)..... | 102 |
| .....do..... | D. | 60 | 6 | 50 | ..... | ..... | 1 | 1904 | ..do.... | ..... | 103 |
| .....do..... | D. | 59 | 6 | 50 | ..... | ..... | 2½ | 1904 | ..do.... | ..... | 104 |
| Geo. W. Carman. | D. | 27½ | 6 | 25 | ..... | ..... | 30 | 1904 | ..do.... | Soft. (L.)..... | 105 |
| .....do..... | D. | 80 | 6 | 58 | ..... | ..... | 5 | 1904 | ..do.... | Water at 35 feet. Soft. (L. S.) | 106 |
| .....do..... | D. | 48 | 6 | 47 | ..... | ..... | 5 | 1904 | ..do.... | Water at 28 feet. Soft. (L.) | 107 |
| .....do..... | D. | 41 | 6 | ..... | ..... | ..... | ..... | 1904 | ..do.... | Water at 30 and 35 feet. Pumps 6 gallons an hour. (L.) | 108 |

## MICHIGAN.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cartwright & Sherry. | M. | 750 | 8 | ..... | —30 | ..... | ..... | 1904 | Water. | Yields abundance of strong mineral water. (L. S.) | 109 |
| F. Howard..... | C. | 106 | 3 | 105 | —44 | ..... | ..... | 1904 | ..do.... | Iron and sulphur. (L. S.) | 110 |
| ..... | O. | 271 | 5 | ..... | ..... | ..... | ..... | 1900 | Salt.... | (L.)..... | 111 |
| Fred Taylor.... | D. | 364 | 6–5 | 264 | ..... | ..... | 100 | 1904 | Water. | (L. S.)..... | 112 |
| F. F. Copeland. | C. | 100 | .... | ..... | ..... | 20 | ..... | 1904 | ..do.... | One of a series of 9 wells. All about same depth and yield. Temperature 42°. (L. S.) | 113 |
| Fred Sherer.... | O. | 97 | 2 | 97 | ..... | ..... | ..... | 1904 | ..do.... | Water at 32 feet. Hard. | 114 |
| ..... | M. | 184 | .... | ..... | ..... | ..... | ..... | 1904 | ..do.... | ..... | 115 |
| J. A. Colwell... | D. | 95 | .... | ..... | ..... | ..... | ..... | 1904 | ..do.... | No water. (L. S.). | 116 |
| Lewis Maule... | C. | 105 | 2 | ..... | —97 | ..... | ..... | 1904 | ..do.... | (L.)..... | 117 |

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*Summary of well drilling*

## MINNESOTA.

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 118 | Freeborn | Albert Lea | 102 | 21 | 5 | John Tennis | J. E. Sharp |
| 119 | Kandiyohi | Atwater | | | | City of Atwater | J. F. McCarthy |
| 120 | Polk | Fertile | | | | Northern Pacific Rwy. Co. | do |
| 121 | Steele | Blooming Prairie | | | | H. Shaw | |

## MISSISSIPPI.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| a122 | Hancock | Bay St. Louis | | | | Peerless Oyster Co. | John A. Sutter |
| 123 | do | Waveland | | | | Chas. L. Hopkins | do |
| 124 | Harrison | Pass Christian, 3 m. E. of. | | | | Misses Miltenberger. | do |
| 125 | do | Wortham | | | | Gulf and Ship Island R. R. Co. | do |
| a126 | Jackson | Mosspoint | | | | L. N. Dantzler Lumber Co. | do |

## MISSOURI.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| a127 | Randolph | Moberly | | | | | A. P. Phillips |
| 128 | St. Louis City | St. Louis | 46 N. | 6 E. | | C. D. Garnett | H. W. Steinsiek |
| a129 | do | do | | | | Welle Boultler Baking Co. | C. S. Wise |

## MONTANA.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 130 | Flathead | Kintla Lake | | | | Butte Oil Co | |
| 131 | Teton | Chief Mountain Lake | | | | | |

a See detailed record at end of table.

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*reported in 1904*—Continued.

## MINNESOTA.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. Flow. | Yield per minute. Pump. | Year completed. | Kind of well. | Remarks. | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| J. E. Sharp..... | C. | 127 | 2 | 115 | −104 | ..... | ..... | 1904 | Water. | Hard water in abundance. (L. S.) | 118 |
| E. Espy..... | D. | 453 | 8–6 | 414 | ..... | ..... | 100 | 1904 | ..do.... | Water strata at 45, 100, and 310 feet. (L. S.).... | 119 |
| E. Christofferson. | D. | 296 | 8–6 | 280 | ..... | −25 | 100 | 1904 | ..do.... | (L. S.)..... | 120 |
| Jim O'Neil..... | D. | 100 | 2 | ..... | + 2 | ..... | ..... | 1904 | ..do.... | Water soft..... | 121 |

## MISSISSIPPI.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| John L. Ford... | D. | 897 | 3 | 818 | ..... | 225 | ..... | 1904 | Water. | Water at 690 feet, flowed 50 gallons a minute. (L. S.) | 122 |
| .....do..... | D. | 775 | 3 | 700 | ..... | 165 | ..... | 1904 | ..do.... | Water at 350 feet, (L. S.) | 123 |
| John Ford..... | C. | 747 | 3 | 727 | ..... | 225 | ..... | 1904 | ..do.... | Water stratum 628 to 747 feet. (L. S.) | 124 |
| Archie Dickson. | C. | 590 | 3 | 500 | ..... | 100 | ..... | 1904 | ..do.... | Water began to flow at 110 feet. (L. S.) | 125 |
| John L. Ford... | D. | 790 | 3 | 770 | ..... | 135 | ..... | 1904 | ..do.... | (L. S.)..... | 126 |

## MISSOURI.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A. P. Phillips... | C. | 2,100 | .... | ..... | ..... | ..... | ..... | 1902 | Oil..... | Water at 632 feet. Brine at 870 and 1,215 feet. Water rose to −70 feet. (L.) | 127 |
| H. W. Steinsiek. | C. | 518 | 5¼–4¼ | 500 | ..... | ..... | 15 | 1904 | Water. | (L. S.)..... | 128 |
| Ed. Meloy..... A. W. Dickinson. | D. | 650 | 8–4 | ..... | ..... | ..... | ..... | 1904 | Oil..... | Water at 140 and 185 feet. A showing of oil at 280, 305, 510, and 600 to 650 feet. Dry hole. (L. S.) | 129 |

## MONTANA.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ..... | M. | 1,405 | .... | ..... | ..... | ..... | ..... | 1904 | Oil..... | ..... | 130 |
| ..... | M. | 1,020 | .... | ..... | ..... | ..... | [b] 30 | ..... | ..do.... | Lubricating oil well. Just north of United States boundary line. | 131 |

[b] Barrels a day.

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*Summary of well drilling*

## NEBRASKA.

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 132 | Buffalo | Shelton | | | | Village of Shelton. | |
| 133 | Dodge | Scribner | | | | Chicago and Northwestern Rwy. Co. | |
| 134 | Saunders | Cedar Bluffs | | | | City | |
| 135 | Webster | Rosemont | | | | | |

## NEW HAMPSHIRE.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 136 | Belknap | New Hampton | | | | Hanna M. Walker. | G. W. Patterson. |
| 137 | Merrimack | New London | | | | Chas. G. Davis. | Artesian well and Supply Co. |
| 138 | do | Potter place | | | | Shepard & Gould. | do |
| 139 | do | New London | | | | Chas. Shepard. | do |
| 140 | Sullivan | Burkehaven | | | | Tuxbury Bros. | do |

## NEW JERSEY.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| a141 | Atlantic | Pleasantville | | | | Water Department, Atlantic City. | Thos. B. Harper. |
| 142 | do | do | | | | do | do |
| 143 | Cape May | Woodbine | | | | Woodbine Land Co. | Ridpath & Potter. |
| 144 | Hudson | Jersey City | | | | Jno. Mehl & Co. | P. H. and J. Conlan. |
| 145 | Middlesex | Keasbey | | | | Wm. Dunham | W. R. Osborne |
| 146 | do | do | | | | Mrs. Jas. A. Noye | do |
| 147 | do | Metuchen | | | | Mr. Avery | do |
| 148 | do | do | | | | Mr. Berkold | do |
| 149 | do | Perth Amboy | | | | Barber Asphalt and Paving Co. | do |
| 150 | do | Perth Amboy, 3 m. S. of | | | | Chas. Bloomfield. | do |
| 151 | do | Perth Amboy | | | | W. J. Daniels | do |
| 152 | do | do | | | | Raritan Coffee Works. | do |
| 153 | do | do | | | | Standard Underground Cable Co. | Stotthoff Bros. |
| 154 | do | Amboy | | | | George Seamans | W. R. Osborne |
| 155 | do | do | | | | R. N. and H. Valentine. | do |

a See detailed record at end of table.

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*reported in 1904*—Continued.

## NEBRASKA.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. Flow. | Yield per minute. Pump. | Year completed. | Kind of well. | Remarks. | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| ..... | M. | 52½ | .... | 45½ | ..... | ..... | ..... | ..... | Water. | One of a series of wells. (L.) | 132 |
| L. C. Dewitt.... | D. | 78 | 6 | ..... | −12 | ..... | ..... | 1904 | ..do.... | Two wells pump together 10,000 gallons per hour. (L.) | 133 |
| W. A. Morris... | M. | 124 | 8 | ..... | ..... | ..... | 147 | 1904 | ..do.... | Water-bearing bed at 57½ feet. Water hard. | 134 |
| Class Rose..... | M. | 409 | .... | ..... | ..... | ..... | ..... | ..... | ..... | Iron ore at 375 feet. Oil at 379 feet. (L.) | 135 |

## NEW HAMPSHIRE.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Geo. W. Carman. | D. | 75 | 6 | ..... | ..... | ..... | ..... | 1904 | Water. | No water. Abandoned. (L. S.) | 136 |
| N. F. Harris.... | .... | 50 | 8 | ..... | −25 | ..... | 4 | 1904 | ..do.... | Water soft. Temperature, 47°. | 137 |
| .....do..... | D. | 38 | 6 | 38 | −10 | ..... | 30 | ..... | ..do.... | Water soft..... | 138 |
| .....do..... | D. | 218 | 8 | 195 | −10 | ..... | 4 | 1904 | ..do.... | Water soft. Temperature, 50°. (L. S.) | 139 |
| .....do..... | D. | 70 | 8 | 70 | −10 | ..... | 5 | 1904 | ..do.... | Water soft. Temperature, 47°. | 140 |

## NEW JERSEY.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ..... | M. | 320 | 4½ | ..... | ..... | ..... | ..... | 1903 | Water. | Test well. Water at 35, 80, and 138 feet. Not pumped. (L. S.) | 141 |
| ..... | M. | 190 | 6 | 136 | ..... | 50 | ..... | 1904 | ..do.... | Well No. 2. Water stratum 180 to 190 feet. (L. S.) | 142 |
| ..... | C. | 152½ | 6–4 | 125 | ..... | ..... | 60 | 1904 | ..do.... | Water at 6, 106, and 140 feet. (L.) | 143 |
| ..... | M. | 1,020 | 8 | ..... | −110 | ..... | 125 | 1898 | ..do.... | Water at 780 and 1,000 feet. Soft. Temperature 54°. | 144 |
| ..... | C. | 85 | 4 | 85 | ..... | ..... | ..... | 1904 | ..do.... | (L.)..... | 145 |
| ..... | C. | 114 | 4 | 90 | ..... | ..... | ..... | 1904 | ..do.... | (L.)..... | 146 |
| ..... | M. | 32 | 4 | 32 | ..... | ..... | ..... | 1904 | ..do.... | (L.)..... | 147 |
| ..... | C. | 56 | 4 | 56 | ..... | ..... | ..... | 1904 | ..do.... | Water in abundance. (L.) | 148 |
| ..... | C. | 50 | 6 | 45 | ..... | ..... | 25<br>50 | 1904 | ..do.... | Two wells. (L.).. | 149 |
| ..... | C. | 63 | .... | 63 | ..... | ..... | ..... | 1904 | ..do.... | (L.)..... | 150 |
| ..... | C. | 52 | .... | 45 | ..... | ..... | ..... | 1904 | ..do.... | (L.)..... | 151 |
| ..... | C. | 150 | 8–4 | ..... | ..... | ..... | 140 | 1904 | ..do.... | (L.)..... | 152 |
| ..... | C. | 158 | 6 | 135 | −23 | 70 | ..... | ..... | ..do.... | Well No. 5. Water stratum at 90 feet. (L.) | 153 |
| ..... | C. | 75 | 4 | 60 | ..... | ..... | ..... | ..... | ..do.... | (L.)..... | 154 |
| ..... | C. | 50 | 4 | 50 | ..... | ..... | ..... | 1904 | ..do.... | ..... | 155 |

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*Summary of well drilling*

**NEW JERSEY—Continued.**

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 156 | Middlesex | Woodbridge | | | | T. F. Dunnigan | W. R. Osborne |
| a157 | Monmouth | Atlantic Highlands | | | | Borough of Atlantic Highlands. | Ambrose Mathews. |
| 158 | Union | Cranford | | | | Henry Deyan | F. T. Cladek |
| 159 | do | Elizabeth on Rahway | | | | John Bedon | do |
| 160 | do | Westfield | | | | Bertram E. Ball | do |
| 161 | do | do | | | | Charles Peifer | do |
| 162 | Warren | Martens Creek | | | | Seltz Brewing Co. | Stotthoff Bros. |

**NEW MEXICO.**

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 163 | San Miquel | Chapelle | | | | A. T. and S. F. R. R. | C. H. McVay |

**NEW YORK.**

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 164 | Allegany | Ceres McDonald farm, well No. 1. | | | | J. T. Barnes | E. C. Strait |
| 165 | Herkimer | Newport | | | | Condensed Milk Co. | Alex. T. Gibson. |
| 166 | Madison | Georgetown station | | | | Mutual Milk and Cream Co. | |
| 167 | Monroe | North Rush | | | | State Industrial School. | E. A. Jenkins |
| 168 | Nassau b | Freeport | | | | City of Freeport | |
| b69 | do | Laurelton | | | | E. C. Henderson | E. K. Hutchinson & Son. |
| 170 | do | do | | | | do | do |
| 171 | do | Oyster Bay (near Mill Neck). | | | | W. R. Peters | |
| 172 | Onondaga | Bromley, 8 m. S. of | | | | School district No. 11. | |
| 173 | do | Tully | | | | Ovid S. Trail | |
| a174 | do | do | | | | Solway Process Co. | |
| 175 | Richmond | Sea Breeze | | | | | W. R. Osborne |
| 176 | Suffolk | Brentwood | | | | Wm. H. Moffit | |
| 177 | do | Cold Spring Harbor | | | | W. Jennings | Hudson Engineering Co |
| 178 | do | Pinelawn | | | | A. B. Sobother | |
| 179 | Westchester | Harrison, 3 m. N. of | | | | John W. Sterling | George R. Bliss. |
| 180 | do | do | | | | do | do |

a See detailed record at end of table.
b For additional records of wells on Long Island see Professional Paper No. 44.

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*reported in 1904*—Continued.

NEW JERSEY—Continued.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. Flow. | Yield per minute. Pump. | Year completed. | Kind of well. | Remarks. | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| ..... | C. | 32 | .... | 32 | ..... | ..... | ..... | ..... | Water . | ..... | 156 |
| Elias Brower ... | M. | 450 | 4¼ | 412 | ..... | 20 | 125 | 1904 | ..do .... | (L. S.)..... | 157 |
| F. T. Cladek.... | C. | 121 | 6 | ..... | −17 | ..... | 14 | 1904 | ..do .... | ..... | 158 |
| .....do ..... | C. | 67 | 4¼ | 60 | −18 | ..... | 21 | 1904 | ..do .... | (L. S.)..... | 159 |
| .....do ..... | C. | 119 | 4¼ | 108 | −29 | ..... | 20 | 1904 | ..do .... | (L. S.)..... | 160 |
| .....do ..... | C. | 96 | 5 | 90 | ..... | ..... | 18 | 1904 | ..do .... | (L. S.)..... | 161 |
| H. S. Barnett.... | C. | 140 | 6 | 120 | −70 | ..... | 20 | 1904 | ..do .... | (L.) ..... | 162 |

NEW MEXICO.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| J. Scully.....<br>J. Polley.....<br>W. Canfield .... | M. | 960 | 13–8 | 930 | −310 | ..... | 25 | 1903 | Water . | Water-bearing beds at 120 and 380 feet. (L.) | 163 |

NEW YORK.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| E. C. Stralt.....<br>D. Brumbaugh . | C. | 1802 | 8–6¼ | ..... | ..... | ..... | ..... | 1904 | Gas.... | Oil at 710 and 1,060 feet; gas at 500 and 1,110 feet; yield, 15,000 cubic feet a day. (L. S.) | 164 |
| ..... | C. | 96 | .... | 90 | −10 | ..... | ..... | 1904 | Water . | ..... | 165 |
| Lawson B. Cuyle | M. | 75 | .... | 60 | ..... | ..... | ..... | ..... | ..do .... | ..... | 166 |
| E. A. Jenkins... | C. | 115 | 5¼ | ..... | − 5 | ..... | 50 | 1904 | ..do .... | ..... | 167 |
| F. W. Miller.... | M. | ..... | 10 | ..... | ..... | ..... | 600 | 1904 | ..do .... | Series of wells .... | 168 |
| ..... | M. | 58 | 8 | ..... | −43 | ..... | ..... | ..... | ..do .... | Well No. 1. (L. S.). | 169 |
| ..... | M. | 126 | 6 | ..... | −42 | ..... | ..... | ..... | ..do .... | Well No. 2; 30 feet from No. 1. (L. S.) | 170 |
| C. H. Davis..... | D. | 72 | .... | 40 | ..... | ..... | ..... | 1904 | ..do .... | Abundance of water. (S.) | 171 |
| L. C. Barber.... | D. | 112 | 5 | ..... | ..... | ..... | 7 | 1904 | ..do .... | ..... | 172 |
| .....do ..... | D. | 104 | 6 | ..... | ..... | ..... | 7 | 1904 | ..do .... | ..... | 173 |
| ..... | O. | 973 to 1,526 | ..... | ..... | ..... | ..... | ..... | 1899 to 1900 | Brine.. | 21 wells. Salt beds at depths between 935 and 1,520 feet. (L.) | 174 |
| ..... | C. | 100 | .... | ..... | − 3 | ..... | 25 | 1904 | Water . | Irony. (L.) ..... | 175 |
| J. Elliott..... | D. | 37 | .... | ..... | −27 | ..... | ..... | 1904 | ..do .... | ..... | 176 |
| Frank Wankel.. | D. | 400 | 8 | 280 | ..... | ..... | 75 | 1904 | ..do .... | Water at 276 and 308 feet. (L. S.) | 177 |
| J. Elliott..... | D. | 50 | .... | ..... | −40 | ..... | ..... | 1904 | ..do .... | ..... | 178 |
| George R. Bliss. | C. | 255 | 6 | 250 | −29 | ..... | 18 | 1904 | ..do .... | Well No. 1. Water at 50, 85, 205, 230, and 245 feet. (L. S.) | 179 |
| .....do ..... | C. | 212 | 6 | 212 | − 4 | ..... | 5 | 1904 | ..do .... | Well No. 2. Water at 160 and 200 feet. (L.) | 180 |

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*Summary of well drilling*

## NORTH CAROLINA.

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 181 | Lenoir | Kinston | | | | City of Kinston | |

## OHIO.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 182 | Cuyahoga | Cleveland | | | | Hamby Realty Co. | Dibble & Ernest. |
| 183 | do | Gates Mill | | | | S. P. Baldwin | do |
| 184 | do | do | | | | E. A. Foot | do |
| 185 | do | do | | | | Mr. Ginrich | do |
| 186 | do | do | | | | F. T. Showls | do |
| 187 | do | South Euclid | | | | Mr. Cousins | do |
| 188 | do | do | | | | H. Faust | do |
| 189 | do | do | | | | Mrs. K. Martins | do |
| 190 | do | do | | | | F. McFarland | do |
| 191 | do | South Euclid, 3 m. NW. of. | | | | Northern Ohio Squab Co. | do |
| 192 | do | South Euclid | | | | R. E. Smith | do |
| 193 | Geauga | Auburn | | | | Corwin Hall | do |
| 194 | do | Chardon | | | | F. Curtis | do |
| 195 | do | do | | | | H. Hadlon | do |
| 196 | do | do | | | | Kiser & Winchel | do |
| 197 | do | do | | | | William Martins | do |
| 198 | do | do | | | | F. Stafford | do |
| 199 | do | Ford | | | | W. B. Cleveland | do |
| 200 | do | do | | | | do | do |
| a201 | Hancock | Findlay | | | | C. L. Casterline | G. L. Cusac |
| 202 | do | Portage Twp. Smith farm. Well No. 8. | | | 31 | Bradford Oil Co | |
| 203 | Licking | Utica, 7 m. W. of | | | | Central Ohio Natural Gas and Fuel Co. | Pearsall & Co. |
| 204 | Mahoning | Youngstown, 2 m. W. of. | | | | W. H. Lewis | |
| 205 | do | Youngstown, 3 m. E. of. | | | | do | |
| 206 | do | do | | | | do | |
| 207 | do | Youngstown, 2 m. N. of. | | | | do | |
| 208 | do | Youngstown, 6 m. N. of. | | | | do | |
| 209 | Marion | Martel | | | | | |
| 210 | Montgomery | Dayton | | | | Dayton State Hospital. | Jas. Kinney, jr. |

a See detailed record at end of table.

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*reported in 1904*—Continued.

## NORTH CAROLINA.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. Flow. | Yield per minute. Pump. | Year completed. | Kind of well. | Remarks. | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| W. C. Martin ... | M. | 310 | .... | ..... | ..... | ..... | ..... | 1904 | Water . | (L. S.)..... | 181 |

## OHIO.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ..... | C. | 30<br>80<br>85 | ... | ..... | ..... | ..... | ..... | 1904 | Water . | Three wells. Small yield. | 182 |
| E. Prince ..... | .... | 148 | 8 | ..... | ..... | ..... | 3 | 1904 | ..do .... | (L.) ..... | 183 |
| ..... | C. | 59 | 5½ | 59 | ..... | ..... | 4 | 1904 | ..do .... | (L.) ..... | 184 |
| ..... | C. | 169 | 4 | 169 | − 9 | ..... | 8 | 1904 | ..do .... | Well in old river channel. | 185 |
| ..... | C. | 186 | .... | ..... | −40 | ..... | 6 | 1904 | ..do .... | (L.) ..... | 186 |
| E. Prince ..... | C. | 87 | 5½ | 87 | ..... | ..... | 2 | 1904 | ..do .... | (L.) ..... | 187 |
| E. D. Ernest..... | C. | 123 | 5½ | 110 | ..... | ..... | 8 | 1904 | ..do .... | ..... | 188 |
| E. Prince ..... | C. | 50 | 5½ | 48 | ..... | ..... | 3 | 1904 | ..do .... | ..... | 189 |
| .....do ..... | C. | 22 | 5½ | ..... | ..... | ..... | 2 | 1904 | ..do .... | ..... | 190 |
| .....do ..... | C. | 67 | 5½ | ..... | ..... | ..... | 2 | 1904 | ..do .... | ..... | 191 |
| E. D. Ernest..... | C. | 121 | 5½ | 120 | −15 | ..... | 24 | 1904 | ..do .... | (L. S.) ..... | 192 |
| ..... | C. | 40 | 5½ | ..... | ..... | ..... | 2 | 1904 | ..do .... | ..... | 193 |
| ..... | C. | 39 | 5½ | ..... | ..... | ..... | 2 | 1904 | ..do .... | ..... | 194 |
| ..... | C. | 186 | 5½<br>4½ | ..... | ..... | ..... | ..... | 1903 | ..do .... | All quicksand below 40 feet. | 195 |
| ..... | C. | 75 | 4½ | ..... | ..... | ..... | 6 | 1904 | ..do .... | Soft..... | 196 |
| George Waite... | C. | 64 | 4½ | 64 | ..... | ..... | 5 | 1904 | ..do .... | ..... | 197 |
| ..... | C. | 38 | 5½ | ..... | ..... | ..... | 2 | 1904 | ..do .... | ..... | 198 |
| ..... | C. | 260 | 7<br>5½<br>4½ | ..... | ..... | ..... | ..... | 1903 | ..do .... | Water-bearing beds at 85 and 260 feet. | 199 |
| ..... | C. | 103 | 5½ | 100 | ..... | ..... | 8 | 1903 | ..do .... | ..... | 200 |
| O.P.Fike;C.Hill | M. | 1,158 | 6½ | ..... | ..... | ..... | ..... | 1904 | Gas.... | Water at 50 and 60 feet; brine at 540 feet; small amount of gas; well abandoned. (L. S.) | 201 |
| O. P. Fike ..... | M. | 1,414 | .... | ..... | ..... | ..... | ..... | 1904 | Oil .... | Oil, 19 feet in Trenton; second pay, 34 feet in. (L. S.) | 202 |
| ..... | C. | 2,133 | 6½ | ..... | ..... | ..... | ..... | 1904 | Gas.... | Yield, 2,500,000 feet first 24 hours. | 203 |
| W. S. Emery.... | O. | 140 | 4½ | 138 | ..... | ..... | 8 | 1904 | Water . | Hard; small quantity of iron. (L.) | 204 |
| .....do ..... | O. | 120 | 6½ | 115 | ..... | ..... | 5 | 1904 | ..do .... | (L.) ..... | 205 |
| .....do ..... | O. | 65 | 4½ | 62 | ..... | ..... | 4 | 1904 | ..do .... | (L.) ..... | 206 |
| .....do ..... | O. | 203 | 8½ | 190 | −60 | ..... | 20 | 1904 | ..do .... | Soft. (L.)..... | 207 |
| .....do ..... | O. | 251 | 5½ | 240 | −10 | ..... | 100 | 1904 | ..do .... | (L.) ..... | 208 |
| G. W. Ward..... | .... | 474 | .... | 450 | ..... | ..... | ..... | ..... | ..do .... | (L.) ..... | 209 |
| ..... | C. | 105 | 10 | ..... | −10 | ..... | 250 | 1900 | ..do .... | Well No. 1..... | 210 |

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*Summary of well drilling*

**OHIO—Continued.**

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 211 | Montgomery .. | Dayton ..... | ..... | ..... | ..... | Dayton State Hospital. | Jas. Kinney, jr.. |
| 212 | .....do ..... | .....do..... | 2 | 6 | 29 | A. Makley..... | W. G. Teeter.... |
| 213 | .....do ..... | Miamisburg..... | ..... | ..... | ..... | Village of Miamisburg. | ..... |
| 214 | Seneca ..... | Fostoria..... | ..... | ..... | ..... | F. E. England .... | W. H. Copley... |
| 215 | .....do ..... | .....do..... | ..... | ..... | ..... | .....do ..... | .....do ..... |
| 216 | .....do ..... | .....do..... | ..... | ..... | ..... | Mrs. Flickinger... | .....do ..... |
| 217 | Summit ..... | Near N. end of Summit Lake. | ..... | ..... | ..... | Water Works Co .. | Jas. Kinney, jr.. |
| 218 | .....do ..... | .....do..... | ..... | ..... | ..... | .....do ..... | .....do ..... |
| 219 | .....do ..... | Barberton..... | ..... | ..... | ..... | Pittsburg Valve and Fittings Co. | .....do ..... |
| 220 | .....do ..... | Boston ..... | ..... | ..... | ..... | Harry Dayton .... | Dibble & Ernest. |
| 221 | Trumbull ..... | Cortland. (Hadsell well.) | ..... | ..... | ..... | ..... | ..... |
| 222 | Wayne ..... | Orrville..... | ..... | ..... | ..... | Cyclone Drilling Machine Co. | R. Lambie Drilling Co. |
| 223 | .....do ..... | Orrville ..... | ..... | ..... | ..... | John Jenny ..... | ..... |
| a224 | Wood..... | Portage. Mrs. L. Dienst farm, well No. 2. | 4 | 11 E. | 6 | G. F. Munn & Son. | Frank Clough .. |

**OREGON.**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 225 | Clatsop ..... | Fort Stevens ..... | 8 N. | 10 W. | 5-6 | United States..... | ..... |
| 226 | Multnomah ... | Portland ..... | ..... | ..... | ..... | Sisters of Good Shepherd. | ..... |
| 227 | Sherman ..... | Monkland ..... | ..... | ..... | ..... | D. McLachlan.... | ..... |

**PENNSYLVANIA.**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 228 | Allegheny..... | Braddock ..... | ..... | ..... | ..... | Braddock Water Works. | R. H. Black..... |
| 229 | .....do ..... | .....do..... | ..... | ..... | ..... | William Sherwin. | .....do ..... |
| 230 | .....do ..... | Bunola..... | ..... | ..... | ..... | Mr. Stewart ..... | .....do ..... |
| 231 | .....do ..... | Duquesne..... | ..... | ..... | ..... | Carnegie Steel Co. | .....do ..... |
| 232 | .....do ..... | Homestead ..... | ..... | ..... | ..... | .....do ..... | .....do ..... |

a See detailed record at end of table.

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*reported in 1904*—Continued.

OHIO—Continued.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. Flow. | Yield per minute. Pump. | Year completed. | Kind of well. | Remarks. | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| ..... | C. | ..... | ..... | ..... | ..... | ..... | ..... | 1900 | Water. | Wells Nos. 2 and 3. Wells 500 feet apart, each yields 60 to 70 gallons a minute. | 211 |
| W. G. Teeter.... | C. | 176 | 5½ | 40 | ..... | ..... | ¼ | 1904 | ..do.... | ..... | 212 |
| J. A. Yinglin ... | M. | 50 | 8 | 20 | −20 | ..... | 450 | 1904 | ..do.... | Water soft. Temperature 46°. | 213 |
| W. H. Copley... | C. | 81 | 4½ | 79 | ..... | ..... | ..... | 1904 | ..do.... | ..... | 214 |
| .....do..... | C. | 57 | 4½ | 57 | ..... | ..... | ..... | 1904 | ..do.... | ..... | 215 |
| .....do..... | C. | 45 | 4½ | 44 | ..... | ..... | ..... | 1904 | ..do.... | (L.) ..... | 216 |
| ..... | M. | 125 | .... | 23 | ..... | ..... | 188 | 1904 | ..do.... | Well No. 1. (L.).. | 217 |
| ..... | M. | 150 | .... | 50 | ..... | ..... | 301 | 1904 | ..do.... | Well No. 2. (L.).. | 218 |
| O. D. Thomas... | C. | 85 | 8 | 47 | −20 | ..... | 200 | 1904 | ..do.... | (L. S.)..... | 219 |
| ..... | C. | 70 | 5½ | ..... | ..... | ..... | 4 | 1904 | ..do.... | ..... | 220 |
| ..... | M. | 3,710 | .... | ..... | ..... | ..... | ..... | ..... | ..do.... | Little oil, gas, and salt water at 2,995 feet. Top of salt at 3,239 feet. | 221 |
| R. Lambie..... | D. | 604 | 4½ | ..... | ..... | ..... | ..... | 1904 | ..do.... | Brine at 237 and 588 feet. No oil or gas. (L. S.) | 222 |
| Albert Tracy ... | D. | 193 | 3 | 160 | −12 | ..... | 60 | 1904 | ..do.... | ..... | 223 |
| Frank Clough; Evidence Kirk | O. | 1,262 | 8½ / 6½ | 1,102 | ..... | ..... | b5 | 1904 | Oil..... | (L. S.)..... | 224 |

OREGON.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Charles Palmberg. | M. | 80 | 6 | 80 | −7 | ..... | 40 | 1904 | Water. | Water-bearing beds all the way. Water slightly irony. Temperature 52°. | 225 |
| S. Clifford..... | D. | 140 | .... | 130 | ..... | ..... | ..... | 1904 | ..do.... | ..... | 226 |
| James Tomlin .. | D. | 195 | .... | ..... | ..... | ..... | ..... | 1904 | ..do.... | ..... | 227 |

PENNSYLVANIA.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ..... | C. | 67 | 16 | ..... | −38 | 750 | ..... | 1904 | Water. | Test hole. (L.).. | 228 |
| James Hoffman. | C. | 102 | 5½ | 92 | −55 | ..... | 22 | 1904 | ..do.... | Water-bearing bed at 51 feet. Water soft. (L.) | 229 |
| ..... | C. | 90 | .... | 66 | ..... | ..... | ..... | ..... | ..do.... | (L.) ..... | 230 |
| Joseph Hufman. | C. | 131 | 8¼ | 120 | −38 | ..... | ..... | 1904 | ..do.... | Water-bearing beds at 69, 87, and 95 feet. | 231 |
| ..... | C. | 87 | .... | ..... | ..... | ..... | ..... | ..... | ..do.... | No. 1 test hole. (L.) | 232 |

b Barrels a day.

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*Summary of well drilling*

PENNSYLVANIA—Continued.

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 233 | Allegheny | Homestead | | | | Carnegie Steel Co. | R. H. Black |
| 234 | do | do | | | | Homestead Water Works. | do |
| 235 | do | do | | | | City of Homestead | |
| 236 | do | Pittsburg | | | | H. S. Leighton | R. H. Black |
| 237 | do | Wilkinsburg | | | | Texter Lumber Co. | Liberty Well Co. |
| 238 | Butler | Renfrew. Wallace farm, well No. 2. | | | | John Humphrey & Co. | Gibson & Bovard. |
| 239 | Chester | East Downingtown | | | | Northwood Cemetery Co. | Waterman Bros. |
| 240 | Clearfield | Dubois | | | | | J. S. Bean |
| 241 | Forest | Delight, N. P. Wheeler farm, well No. 32. | | | | Forest Gas Co | C. E. Gesin |
| 242 | Greene | Higbee, F. B. Morris farm, well No. 1. | | | | South Penn Oil Co. | R. D. Mead & Co. |
| a243 | do | Higbee, L. C. Grim farm, well No. 6. | | | | do | do |
| a244 | do | Morris Twp., John Lewis farm, well No. 1. | | | | Venture Oil Co | F. S. Black |
| 245 | do | Spring Hill Twp | | | | Hope Gas Co | John McCool |
| 246 | do | Spring Hill Twp. Perry Pethel No. 1. | | | | | |
| 247 | Lawrence | Robinson Crossing | | | | Hughes Well | |
| 248 | Montgomery | Port Kennedy | | | | Michel Eret | Thomas B. Harper. |
| 249 | Warren | Deerfield Twp., Dallas Brooks farm, well No. 1. | | | | Josiah G. Winger & Co. | Josiah G. Winger. |
| 250 | do | Deerfield Twp., Dell Thomas farm, well No. 1. | | | | Stanton Oil Co | do |

a See detailed record at end of table.

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*reported in 1904*—Continued.

PENNSYLVANIA—Continued.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. Flow. | Yield per minute. Pump. | Year completed. | Kind of well. | Remarks. | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| ..... | C. | 85 | .... | ..... | ..... | ..... | ..... | ..... | Water . | No. 2 test hole. (L.) | 233 |
| ..... | C. | 70 | .... | ..... | −23 | ..... | ..... | ..... | ..do .... | Test well. (L.) .. | 234 |
| ..... | M. | 70 | 12 | ..... | ..... | ..... | ..... | ..... | ..do .... | Series of 16 wells. (L.) | 235 |
| ..... | C. | 58 | 8–5¼ | ..... | ..... | ..... | ..... | 1904 | ..do .... | Water-bearing beds at 40 and 52 feet. (L.) | 236 |
| E. S. Kahl..... | D. | 126 | .... | ..... | ..... | ..... | *b* 300 | 1904 | ..do .... | Water-bearing bed at 71 feet. (L.) | 237 |
| Bovard & Snider. | O. | 1,780 | 8¼–6¼ | ..... | 1,750 | ..... | *b* 11 | 1904 | Oil .... | Water-bearing beds at 170 and 600 feet. (L. S.) | 238 |
| ..... | C. | 82 | 5¼ | 71 | ..... | ..... | 6 | 1904 | Water . | Water at 37 feet. | 239 |
| J. S. Bean..... | C. | 3,006 | .... | ..... | ..... | ..... | ..... | 1902 | Oil .... | Fresh water at 110 feet; salt water at 620 and 1,430 feet. Dry hole. (L. S.) | 240 |
| R. H. McDonald; William Gesin. | D. | 1,225 | 8–5¼ | 80 | ..... | (*c*) | ..... | 1904 | Gas .... | Hard water at 80 feet. (L. S.) | 241 |
| Jim George; W. Oslimbaugh. | M. | 3,337 | 10–8–6–5 | ..... | ..... | ..... | ..... | 1901 | Oil .... | Pittsburg coal at 1,022 feet; brine at 1,862 feet. Dry hole. (L.) | 242 |
| J. J. Reed; William Moriarty. | D. | 3,076 | 13–10–8–6 5 | 2,969 | ..... | ..... | *b* 10 | 1904 | ..do .... | Pittsburg coal at 927 feet. (L.) | 243 |
| H. A. Reardon; F. Bell. | D. | 2,965 | 13–10–8–6 | ..... | ..... | ..... | ..... | 1904 | Gas .... | Pittsburg coal at 935 feet; gas at 2,940 feet. (L.) | 244 |
| John Noels; E. J. Duck. | D. | 3,434 | 10–8¼–6¼–5 | ..... | ..... | ..... | ..... | 1904 | ..do .... | Gas at 3,369 feet. Pressure, 900 pounds. (L.) | 245 |
| Elmer Duck.... | D. | 3,234 | 10–8¼–6¼–5 | ..... | ..... | ..... | ..... | ..... | ..do .... | Pittsburg coal at 996 feet; gas at 3,183 and 3,228 feet. (L.) | 246 |
| ..... | M. | 3,830 | 8–6¼ | ..... | ..... | ..... | ..... | 1904 | ..... | Water and oil at 240 feet; gas at 500, 575, and 825 feet. Abandoned. | 247 |
| J. B. McGuckin . | D. | 581 | 8 | 530 | ..... | ..... | 130 | 1904 | Water . | Water at 90 and 500 feet. Water hard. (L. S.) | 248 |
| Jay O. Winger.. | O. | 831 | 8–5¼ | 565 | ..... | ..... | *b* 13 | 1887 | Oil .... | Oil, gas, and salt water at 565 and 775 feet. Well abandoned. (L.) | 249 |
| .....do..... | C. | 765 | 8–5¼ | 728 | ..... | ..... | *b* ¼ | 1896 | ..do .... | Showing of oil at 245 and 485 feet. Well pumped but a short time. (L.) | 250 |

*b* Barrels a day. *c* 10,000 cubic feet a day.



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*Summary of well drilling*

PENNSYLVANIA—Continued.

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 251 | Warren | Deerfield Twp., John Holden farm, well No. 1. | | | | Winger & Nichol | Josiah G. Winger. |
| 252 | do | Deerfield Twp., Philadelphia tract, well No. 1. | | | | do | do |
| 253 | do | Deerfield Twp., Reno land, well No. 5. | | | | Stanton Oil Co | do |
| a254 | do | Eldred Twp., Adams farm, well No. 11. | | | | do | do |
| 255 | do | Eldred Twp., Adams farm, well No. 19. | | | | do | do |
| 256 | do | Eldred Twp., M. Cartright farm, well No. 1. | | | | do | do |
| a257 | do | Eldred Twp., M. Cartright farm, well No. 2. | | | | do | do |
| 258 | do | Eldred Twp., M. Cartright farm, well No. 3. | | | | do | do |
| 259 | do | Eldred Twp., James Cochran farm, well No. 1. | | | | Devonian Oil Co | do |
| 260 | do | Eldred Twp., Ellis farm, well No. 6. | | | | Stanton Oil Co | do |
| 261 | do | Eldred Twp., Ellis farm, well No. 11. | | | | do | do |
| 262 | do | Eldred Twp., Lamarie Lot, well No. 4. | | | | do | E. Meely |
| 263 | do | Eldred Twp., Lamarie Lot, well No. 16. | | | | do | Josiah G. Winger. |
| 264 | do | Eldred Twp., Lot No. 147, well No. 1. | | | | Pardee estate | do |
| 265 | do | Eldred Twp., Philadelphia tract, well No. 1. | | | | Tait & Paterson | do |
| a266 | do | Eldred Twp., Philadelphia tract, well No. 2. | | | | do | do |

a See detailed record at end of table.

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*reported in 1904*—Continued.

PENNSYLVANIA—Continued.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. | | Year completed. | Kind of well. | Remarks. | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Flow. | Pump. | | | | |
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| Jay O. Winger.. | C. | 837 | 8–5¼ | 813 | ..... | ..... | [b]1 | 1898 | Oil .... | Fresh water at 100 feet; salt water at 305 feet; oil and salt water at 560 feet; gas at 807 feet. (L.) | 251 |
| J. G. and J. O. Winger. | C. | 677 | 8–6¼ | 406 | ..... | ..... | [b]¼ | 1898 | ..do .... | Salt water at 170 feet. (L.) | 252 |
| J. O. Winger... | C. | 621 | 8–5¼ | ..... | ..... | ..... | ..... | 1889 | ..do .... | Fresh water at 50 feet; oil, gas, and salt water at 315 feet; salt water at 576 feet; rose 200 feet. Abandoned. (L.) | 253 |
| J. O. and J. J. Winger. | C. | 817 | 8–5¼ | 740 | ..... | ..... | [b]20 | 1900 | ..do .... | Salt water at 750 feet. (L.) | 254 |
| Jay O. Winger.. | C. | 826 | 8–5¼ | 797 | ..... | ..... | [b]20 | 1904 | ..do .... | Fresh water at 275 feet; oil and gas at 758 feet. (L.) | 255 |
| J. G. and J. O. Winger. | C. | 499 | 8–5¼ | 482 | ..... | ..... | [b]5 | 1894 | ..do .... | Fresh water stratum at 435 feet. Salt water at 465 feet. (L.) | 256 |
| .....do ..... | C. | 477 | 8–5¼ | 449 | ..... | ..... | [b]65 | 1894 | ..do .... | Now (1904) producing about 2 barrels a day. (L.) | 257a |
| J. G. Winger; W. D. Putnam. | C. | 437 | 5¼ | 408 | ..... | ..... | [b]8 | 1895 | ..do .... | Water and gas sands end and oil sands begin at 397 feet. (L.) | 258 |
| J. G. and J. O. Winger. | C. | 1,250 | 8¼–6¼ | ..... | ..... | ..... | ..... | 1898 | ..do .... | No trace of oil or gas. (L.) | 259 |
| Josiah G. Winger. | C. | 421 | 8–5¼ | 389 | ..... | ..... | [b]6 | 1895 | ..do .... | Salt water at 358 feet. (L.) | 260 |
| J. G. and J. O. Winger. | C. | 424 | 8–5¼ | 428 | ..... | ..... | [b]10 | 1902 | ..do .... | Fresh water, 50 to 187 feet, salt water, 187 to 213 feet. (L.) | 261 |
| ..... | M. | 728 | 8–5¼ | ..... | ..... | ..... | [b]15 | 1899 | ..do .... | (L. S.)..... | 262 |
| ..... | C. | 802 | 16–8–5¼ | ..... | ..... | ..... | ..... | 1904 | ..do .... | Showings of oil at 495 and 740 feet. Abandoned. (L. S.) | 263 |
| J. O. and J. J. Winger. | C. | 510 | 8–5¼ | ..... | ..... | ..... | ..... | 1900 | ..do .... | Oil, gas, and salt water at 226 feet; salt water at 460; rose 200 feet. Abandoned. (L.) | 264 |
| Jay O. Winger; Charles Arters. | C. | 352 | 5¼ | ..... | ..... | ..... | [b]32 | 1891 | ..do .... | Drilled in 1884 by Stewart Bros., and produced 2 barrels a day. Cleaned and reclaimed in 1891. | 265 |
| Charles Arters.. | C. | 375 | 8–5¼ | 334 | ..... | ..... | [b]32 | 1891 | ..do .... | Fresh water at 100 feet; salt water at 150 feet. (L.) | 266 |

[b] Barrels a day.

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*Summary of well drilling*

PENNSYLVANIA—Continued.

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 267 | Warren | Eldred Twp., Philadelphia tract, well No. 3. | | | | Tait & Paterson | Josiah G. Winger. |
| 268 | do | Eldred Twp., Philadelphia tract, well No. 4. | | | | do | do |
| 269 | do | Eldred Twp., Philadelphia tract, well No. 5. | | | | do | do |
| 270 | do | Eldred Twp., Philadelphia tract, well No. 6. | | | | do | do |
| 271 | do | Eldred Twp., Philadelphia tract, well No. 7. | | | | do | do |
| 272 | do | Eldred Twp., Philadelphia tract, well No. 8. | | | | do | do |
| 273 | do | Eldred Twp., W. D. Pierce farm, well No. 1. | | | | Devonian Oil Co | do |
| 274 | do | Eldred Twp., Reno lot, well No. 6. | | | | Stanton Oil Co | do |
| 275 | do | Eldred Twp., Reno lot, well No. 10. | | | | do | do |
| 276 | do | Eldred Twp., Reno lot, well No. 11. | | | | do | do |
| 277 | do | Eldred Twp., Sayers farm, well No. 18. | | | | Rock Oil Co | J. P. Eaton |
| a278 | do | Eldred Twp., Sayers farm, well No. 19. | | | | do | do |
| a279 | do | Eldred Twp., Smith farm, well No. 4. | | | | Stanton Oil Co | Josiah G. Winger. |
| 280 | do | Eldred Twp., E. F. Thomas farm, well No. 1. | | | | E. Thomas and T. Grant. | do |
| 281 | do | Eldred Twp., Wade farm, well No. 1. | | | | Stanton Oil Co | do |

a See detailed record at end of table.

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*reported in 1904*—Continued.

PENNSYLVANIA—Continued.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. | | Year completed. | Kind of well. | Remarks | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Flow. | Pump. | | | | |
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| Charles Arters; J. O. Winger. | C. | 420 | 8–5½ | 383 | ..... | ..... | 26 | 1891 | Oil..... | Fresh water at 152 feet; gas at 371 feet. (L.) | 267 |
| .....do..... | C. | 360 | 8–5½ | 310 | ..... | ..... | *b* 4 | 1891 | ..do.... | Fresh water 20 to 184 feet; rises nearly to surface. (L.) | 268 |
| .....do..... | C. | 461 | 8–5½ | 420 | ..... | ..... | *b* 35 | 1891 | ..do.... | Oil and water rose 200 feet in well. (L.) | 269 |
| .....do..... | C. | 420 | 8–5½ | 377 | ..... | ..... | *b* 20 | 1891 | ..do.... | Now (1904) producing about 1 barrel a day. (L.) | 270 |
| J. G. and J. O. Winger. | C. | 420 | 8–5½ | 384 | ..... | ..... | *b* 7 | 1891 | ..do.... | Proved small well. (L.) | 271 |
| .....do..... | C. | 333 | 8–5½ | 290 | ..... | ..... | *b* 22 | ..... | ..do.... | Yield retarded by large quantity of salt water present. In this pool (Newton) oil and salt water vary proportionately. (L.) | 272 |
| .....do..... | C. | 618 | 6½ | ..... | ..... | ..... | ..... | 1898 | ..do.... | Oil and gas at 354 feet. Casing torn by torpedo. Well abandoned. (L.) | 273 |
| Josiah G. Winger; W. D. Putnam. | C. | 484 | 8–5½ | 519 | ..... | ..... | *b* 5 | 1894 | ..do.... | Much salt water at 512 feet. (L.) | 274 |
| J. G. and J. O. Winger. | C. | 554 | 8–5½ | ..... | ..... | ..... | *b* 10 | 1899 | ..do.... | Showing of oil not sufficient to warrant torpedoing the well. (L.) | 275 |
| Jay O. Winger.. | C. | 615 | 8–5½ | 587 | ..... | ..... | *b* 5 | 1904 | ..do.... | Small showing of oil, gas, and salt water at 313 feet. (L. S.) | 276 |
| Harry Eaton; Orany Proper. | D. | 544 | 8–6½ | 514 | ..... | ..... | *b* 15 | 1904 | ..do.... | Well yields 3 barrels of salt water to 1 of oil. (L. S.) | 277 |
| H. J. Eaton; O. Proper; H. G. Peck. | D. | 520 | 8–6½ | 490 | ..... | ..... | *b* 12 | 1904 | ..do.... | Amount of salt water small. (L. S.) | 278 |
| Jay O. Winger.. | C. | 632 | 8–5½ | 505 | ..... | ..... | *b* 12 | 1904 | ..do.... | Fresh-water sand 140 to 220 feet. Showing of oil at 335 feet. (L. S.) | 279 |
| .....do..... | C. | 690 | 8–5½ | ..... | ..... | ..... | ..... | 1901 | ..do.... | Salt water at 425 feet. Showings of oil at 641 and 666 feet. Well abandoned. (L.) | 280 |
| Oliver Kelly.... | C. | 754 | 8 | ..... | ..... | ..... | ..... | 1889 | ..do.... | Fresh water 40 to 224 feet. Slight traces of oil and gas at 712 feet. Well abandoned. (L.) | 281 |

*b* Barrels a day.

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*Summary of well drilling*

PENNSYLVANIA—Continued.

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 282 | Warren | Eldred Twp., Henry Wheeler farm, well No. 1. | | | | Stanton Oil Co. | Josiah G. Winger. |
| 283 | do | Spring Creek Twp., Frank Hellyer farm, well No. 1. | | | | Devonian Oil Co. | do |
| a284 | do | Southwest Twp., Sturges farm, well No. 25. | | | | Cogswell, Thurston & Co. | B. P. McCool |
| a285 | Washington | Thomas, Speer heirs' farm, well No. 7. | | | | Liberty Oil and Gas Co. | Lyle & McCloy |
| 286 | York | Nashville | | | | William Sprenkel | S. T. Crist |

RHODE ISLAND.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 287 | Kent | Warwick | | | | Nelson W. Aldrich | |
| 288 | Newport | Sakonnet | | | | Edwin W. Winter. | |
| 289 | Providence | Woonsocket | | | | Alsace Worsted Co. | Artesian Well Supply Co. |
| 290 | do | do | | | | Rev. George T. Mahoney. | C. L. Grant |

SOUTH DAKOTA.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 291 | Gregory | Bonesteel | | | | C. & N. W. Rwy. Co. | Matteson & Zeigler. |
| 292 | Hyde | Highmore, 8 m. NW. of. | 114 | 71 | 29 | Mitchell Cattle Co. | Norbeck & Nicholson. |

TENNESSEE.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 293 | Hamilton | Chattanooga | | | | Chattanooga Medicine Co. | |

a See detailed record at end of table.

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*reported in 1904*—Continued.

PENNSYLVANIA—Continued.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. Flow. | Yield per minute. Pump. | Year completed. | Kind of well. | Remarks. | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| Jay O. Winger.. | C. | 497 | 8–5¼ | 434 | ..... | ..... | *b* ¾ | 1895 | Oil..... | Salt water at 442 feet rose 150 feet. Oil at 465 feet. (L.) | 282 |
| J. G. and J. O. Winger. | C. | 484 | 8–5¼ | ..... | ..... | ..... | ..... | 1898 | ..do .... | Fresh water flowed 10 gallons a minute at 198 feet. Showing of oil and gas at 224 and 463 feet. Yield 5 gallons first day. Abandoned. (L.) | 283 |
| B. P. McCool, E. Hare. | C. | 789 | 8¼–5¼ | 760 | ..... | ..... | *b* 5 | 1904 | ..do .... | Fresh water at 55 feet. (L. S.) | 284 |
| McCloy & Rowlee. | D. | 2,275 | 13–10–8–6¼ | 2,252 | ..... | ..... | *b* 15 | 1904 | ..do .... | Water at 80 and 1,082 feet. Pittsburg coal at 336 feet. Gas at 1,285 feet. (L.S.) | 285 |
| S. T. Crist ..... | C. | 120 | 6 | 90 | ..... | ..... | 10 | 1904 | Water . | (L.)..... | 286 |

RHODE ISLAND.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ..... | M. | 502 | 8 | ..... | −10 | ..... | 120 | 1900 | Water . | Water rather hard | 287 |
| ..... | M. | 66 | 6 | 50 | −30 | ..... | ¼ | 1904 | ..do .... | Water soft..... | 288 |
| Frank Mentzer, M. F. Knauf. | D. | 240 | 10–8 | 240 | ..... | ..... | 20 | 1904 | ..do ... | (L. S.) ..... | 289 |
| J. F. Matthews. | C. | 102 | 6 | 44 | ..... | ..... | 17 | 1904 | ..do .... | (L. S.) ..... | 290 |

SOUTH DAKOTA.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Matteson & Zeigler. | C. | 393 | 5¼ | ..... | ..... | ..... | ..... | 1904 | ..... | Test hole. Water stratum 30 to 50 feet. (L. S.) | 291 |
| ..... | M. | 1,397 | 2 | 1,397 | ..... | 137 | ..... | 1902 | ..... | Water at 1,232 feet. Very soft. Temperature 81°. | 292 |

TENNESSEE.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ..... | O. | 250 | 6 | 155 | −100 | ..... | ..... | ..... | Water . | Water at 250 feet. "Abundant supply" of soft water. (S.) | 293 |

*b* Barrels a day.

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*Summary of well drilling*

TEXAS.

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 294 | Bexar | Fort Sam Houston | | | | | |
| 295 | Brazoria | Sandy Point | | | | L. B. Shephard | P. M. Granberry. |
| 296 | do | Velasco, 3½ m. SW. of | | | | Mr. Bryan | |
| 297 | Denton | Denton | | | | College Addition Waterand Power Co. | |
| 298 | El Paso | El Paso, 40 m. N. of | | | | Albert M. Coe | |
| 299 | do | El Paso, 25 m. N. of | | | | J. F. Mahill and Wiley N. Coe. | |
| 300 | Hardin | Batson, Parafine Oil Co., well No. 7. | | | | Texas Drilling Co. | Texas Drilling Co. |
| a301 | Harris | Houston | | | | Houston Water Co. | Gust. Warnecke. |
| a302 | do | Humble, L. W. Long farm, well No. 1. | | | | P. M. Granberry and others. | P. M. Granberry. |
| 303 | do | Humble, 8 m. E. of | | | | Dan E. Kennedy | do |
| 304 | do | Humble, 6½ m. E. of | | | | do | do |
| 305 | Jefferson | Beaumont, 17½ m. SW. of. (Bingham farm.) | | | | Sun Co | Sun Co |
| 306 | Montgomery | Wilburton | | | | I. & G. N. Rwy | |
| 307 | Nacogdoches | Nacogdoches, 13 m. SE. of. | | | | J. M. Thresher | |
| 308 | Nueces | Coldris, 3 m. S. of | | | | Robert Driscoll | |
| 309 | do | do | | | | do | |
| 310 | Tyler | Kountze, 15 m. NW. of. (Reliance No. 2.) | | | | Sun Co | Sun Co |
| 311 | Wilson | Sutherland Springs, Lee farm, well No. 1. | | | | American Mineral Co. | American Mineral Co. |

a See detailed record at end of table.

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*reported in 1904*—Continued.

TEXAS.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. Flow. | Yield per minute. Pump. | Year completed. | Kind of well. | Remarks. | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| ..... | M. | 726 | .... | 705 | +5 | ..... | 200 | 1901 | Water. | Water-bearing beds at 351 and 398 feet. Water at 398 feet salt. (L. S.) | 294 |
| ..... | C. | 1,500 | .... | ..... | ..... | ..... | ..... | 1904 | Oil..... | Prospect well. Artesian water stratum 1,000 to 1,100 feet. | 295 |
| R. T. Clifton.... | D. | 742 | .... | ..... | ..... | ..... | ..... | 1904 | ..do.... | Abandoned at 742 feet. (L. S.) | 296 |
| Luther Myers .. | M. | 592 | 6–4 | 520 | ..... | ..... | 12 | 1904 | Water. | (L. S.)..... | 297 |
| James Sewell... | M. | 160 | 5–6 | 45 | ..... | ..... | ..... | 1898 | ..do.... | "Abundant supply" of soft water. | 298 |
| .....do..... | M. | 350 | 6 | 335 | ..... | ..... | ..... | 1904 | ..do.... | Soft water..... | 299 |
| Joseph Dronot.. | M. | 885 | 4 | ..... | ..... | ..... | *b*50 | 1904 | Oil..... | (L. S.)..... | 300 |
| A. Warnecke ... | O. | 2,025 | 8–6 4 | ..... | ..... | ..... | ..... | 1904 | Water. | Gas at 1,600 feet. One of a series of wells which yield from 1,000 to 800,000 gallons a day each. (L. S.) | 301 |
| W. A. Young.... | C. | 990 | 11½ –6 | 950 | ..... | ..... | *b*100 | 1904 | Oil..... | Gas present in increasing amounts below 600 feet. (L. S.) | 302 |
| ..... | C. | 1,500 | .... | ..... | ..... | ..... | ..... | 1904 | ..do.... | Prospect well; no oil. Little gas at 600 feet. Water-bearing beds 600 to 650 feet and 1,150 to 1,200 feet. | 303 |
| ..... | C. | 1,000 | 6–2½ | ..... | ..... | ..... | ..... | 1904 | ..do.... | Prospect hole. Found neither oil nor gas. | 304 |
| James W. Clark. | D. | 1,515 | 6–4 | ..... | ..... | ..... | ..... | 1904 | ..do.... | Water at 220 and 260 feet. Gas at 240 and 400 feet. Dry hole. (L.) | 305 |
| J. H. Lee ..... | D. | 917 | .... | 892 | ..... | ..... | *b*50 | 1904 | ..do.... | ..... | 306 |
| ..... | O. | 435 | 6 | ..... | ..... | ..... | ..... | 1904 | ..do.... | Water at 68 and 393 feet. Oil at 212, 312, 328, and 360 to 428 feet. Lost on account of water. (L. S.) | 307 |
| Thomas Fowler. | D. | 590 | 5⅜– 4½ | ..... | ..... | 80 | ..... | ..... | Water. | Well No. 4. (L.). | 308 |
| .....do..... | D. | 625 | 5⅜– 4½ | ..... | ..... | 150 | ..... | ..... | ..do.... | Well No. 5. (L.). | 309 |
| James W. Clark. | O. | 1,737 | 6–4 | ..... | ..... | ..... | ..... | 1904 | Oil .... | Dry hole. (L.).... | 310 |
| Hamrick; Pannewitz; Donohue. | D. | 1,500 | .... | ..... | ..... | ..... | ..... | 1904 | ..do.... | Flowing water and gas strata at 14, 71, 419, 973, 1,056, and 1,352 feet. Traces of oil at 415, 628, 775, and 1,352 feet. Dry hole. (L.) | 311 |

*b* Barrels a day.

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*Summary of well drilling*

**UTAH.**

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 312 | Beaver | Beaver | | | | W. Shepherd | |
| 313 | Boxelder | Brigham | 9 | 3 | 14 | W. O. Knudson | |
| 314 | Davise | Farmington | | | | Guffy & Galey | Guffy & Galey |
| 315 | Iron | Lund | | | | San Pedro, Los Angeles and Salt Lake R. R. Co. | L. J. Craig |

**VIRGINIA.**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 316 | Henrico | Richmond | | | | Lewis Ginter | |

**WASHINGTON.**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 317 | King | Ballard | | | | City of Ballard | |

**WEST VIRGINIA.**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| a318 | Kanawha | Forks of Little Sandy. O. Simmons farm, well No. 1. | | | | Lehigh Oil Co | Weiler Bros |
| 319 | Ohio | Wheeling | | | | News Publishing Co. | Jas. Kinney, jr. |
| a320 | Ritchie | Harrisville, F. D. Hawkins, No. 1. | | | | Octo Oil Co | B. W. Publes |
| 321 | Tyler | Van Camp | | | | Lincoln District | Watkins & Co |
| 322 | Wetzel | Folsom. John Robison farm, well No. 17. | | | | South Penn Oil Co. | W. S. Burton |
| a323 | do | Hundred. J. Murphy farm, well No. 1. | | | | Syndicate Oil Co. | Reese, Heasley & Meals. |
| 324 | do | Keough | | | | Hope Natural Gas Co. | John P. Fishel |
| 325 | do | Keough. J. V. Higgins farm, well No. 1799. | | | | Philadelphia Co. | do |

a See detailed record at end of table.
c See detailed record in paper on "Oil and Asphalt Prospects in Salt Lake Basin," by J. M. Boutwell: Contributions to Economic Geology, 1904.

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*reported in 1904*—Continued.

## UTAH.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. Flow. | Yield per minute. Pump. | Year completed. | Kind of well. | Remarks. | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| Geo. G. Halterman. | D. | 330 | .... | ..... | ..... | ..... | ..... | 1904 | Water . | Not flowing ..... | 312 |
| ..... | M. | 30 | 9 | 22 | −22 | ..... | 300 | 1904 | ..do .... | Dug well 9 feet in diameter. | 313 |
| ..... ..... | O. | 2,000 | .... | ..... | ..... | ..... | ..... | ..... | Oil .... | Dry. Well did not reach bed rock. | 314 |
| ..... | C. | 584 | 12–10–8–6 | 573 | ..... | ..... | 50 | ..... | Water . | Salt water at 12 feet. (L.) | 315 |

## VIRGINIA.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ..... | M. | 445 | .... | 410 | ..... | ..... | ..... | ..... | Water . | A little water at 102 feet. (L.) | 316 |

## WASHINGTON.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| G. P. James ..... | M. | 245 | .... | ..... | ..... | ..... | ..... | 1904 | Water . | ..... | 317 |

## WEST VIRGINIA.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| J. G. and G. J. Weiler. | D. | 1,700 | 13–10–8–6¼ | ..... | ..... | (d) | ..... | 1904 | Gas .... | Fresh water at 60 and 155 feet. Hole flowed full of salt water 940 to 990 feet. Gas at 928 feet. (L. S.) | 318 |
| ..... | C. | 250 | .... | ..... | ..... | ..... | ..... | 1904 | Water . | (L. S.) ..... | 319 |
| ..... | O. | 1,875 | .... | ..... | ..... | b 12 | ..... | 1904 | Oil .... | (L. S.) ..... | 320 |
| ..... | C. | 36 | 6 | 35 | −13 | ..... | ..... | 1904 | Water . | Soft..... | 321 |
| H. A. Reardon.. | D. | 3,560 | 10–8–6–5 | ..... | ..... | ..... | b 100 | 1902 | Oil .... | Pittsburg coal at 1,435 feet. Salt water at 2,225 and 2,735 feet. Oil at 3,512 and 3,542 feet. Deepest producing well known. (L.) | 322 |
| E. J. Akins; A. Wild. | D. | 3,236 | 13–10–8¼–6¼ | ..... | ..... | (d) | ..... | 1904 | Gas .... | Pittsburg coal at 1,852 feet. Gas at 1,995, 2,145, and 3,000 feet. Yield. (L.S.) | 323 |
| T. L. Dunlap; C. L. King. | D. | 2,635 | 13–10–8–6 | ..... | ..... | ..... | ..... | 1902 | ..do .... | Water at 60 feet. Pittsburg coal at 530 feet. Gas at 1,675, 1,885, and 2,615 feet. Rock pressure of gas at 1,675 feet, 800 pounds. (L.) | 324 |
| .....do ..... | D. | 3,200 | 10–8–6¼ | ..... | ..... | ..... | ..... | 1904 | ..do .... | Pittsburg coal at 1,095 feet. Gas at 1,866 and 2,460 feet. Salt water at 1,935 feet. Dry hole. (L.) | 325 |

*b* Barrels a day. *d* 500,000 cubic feet a day.

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*Summary of well drilling*

WEST VIRGINIA—Continued.

| No. | County. | Location. | T. | R. | S. | Owner. | Contractor. |
|---|---|---|---|---|---|---|---|
| 326 | Wetzel | Van Camp | | | | J. G. Eddy | Watkins & Co. |
| 327 | do | do | | | | Magnolia district | do |
| 328 | do | do | | | | J. M. Van Camp | do |
| 329 | do | do | | | | Z. S. Watkins | do |
| 330 | do | do | | | | Watkins & Co | do |

WISCONSIN.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 331 | Brown | Askeaton | 21 | 20 | 30 | Cheese factory | J. J. Faust |
| 332 | do | do | 21 | 20 | 28 | John Hart | do |
| 333 | do | Mills Center | | | | Jef. Kimbs | |
| 334 | Columbia | Arlington | | | | David Bullen | |
| 335 | Fond du Lac | Eden Twp | | | 33 | Academy of St. Mary. | P. Roughen |
| 336 | do | Fond du Lac | | | | M. Obrin | do |
| 337 | do | do | | | | Charles Olem | do |
| 338 | do | Waupun | | | | | W. F. Sealy |
| 339 | Grant | Castlerock | 7 N. | 1 W. | 14 | | H. G. Gorder |
| 340 | Iowa | Highland | 7 | 1 | 17 | | do |
| 341 | Juneau | Mather | | | | Appleton Cranberry Co. | E. R. Vandervort. |
| 342 | Outagamie | Dale | 21 | 15 | 30 | Conrad Giebel | I. W. Hills |
| 343 | do | Greenville | 22 | 17 | 19 | Charles H. Fischer | do |
| 344 | do | Hortonville | 22 | 16 | 36 | W. Fischer | do |
| 345 | do | do | 22 | 16 | 13 | Anthony Wallace | do |
| 346 | do | Medina | 21 | 15 E. | 14 | M. Bottrell | do |
| 347 | do | do | 21 | 15 | 26 | Sam Rupple | do |
| 348 | do | Shiocton | 43 | 16 | 36 | John Laird | do |
| 349 | do | South Kaukauna | | | | | |
| 350 | Racine | Corliss | 3 | 22 | 9 | T. F. Cooney | W. M. Bolles |
| 351 | do | Franksville | 4 | 22 E. | 28 | F. Kittenhoffen | do |
| 352 | Vernon | Valley | 14 | 2 W. | 26 | Frank Winchel | |
| 353 | Walworth | Whitewater. (City waterworks.) | | | | C. E. Gray | W. L. Thorne & Co. |
| 354 | Waukesha | Elm Grove | 7 | 20 | 35 | C. K. Reichert | Peter Bauer |
| 355 | Winnebago | Larsen | 20 | 16 E. | 21 | John Lemke | I. W. Hills |
| 356 | do | do | 20 | 16 E. | 21 | Fred Ziehm | do |
| 357 | do | Winneconne | 19 | 15 | 2 | George Barber | do |

WYOMING.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 358 | Sweetwater | Rock Springs, 6 m. S. of. | 18 | 104 W. | 20 | Belgo American Drilling Co. | |

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*reported in 1904*—Continued.

**WEST VIRGINIA**—Continued.

| Driller. | Authority. | Depth. | Diameter. | Depth to principal water or oil supply. | Height of water. | Yield per minute. | | Year completed. | Kind of well. | Remarks. | No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Flow. | Pump. | | | | |
| | | *Ft.* | *In.* | *Ft.* | | *Gals.* | *Gals.* | | | | |
| ..... | C. | 137 | 6 | ..... | −97 | ..... | ..... | 1904 | Water. | Soft water at 70, 126, and 137 feet. | 326 |
| ..... | C. | 41 | 5¼ | 36 | − 8 | ..... | ..... | 1904 | ..do .... | Soft water ..... | 327 |
| ..... | C. | 31 | 6 | 27 | −10 | ..... | ..... | 1904 | ..do .... | .....do ..... | 328 |
| ..... | C. | 60 | 6 | 55 | −20 | ..... | ..... | 1904 | ..do .... | .....do ..... | 329 |
| ..... | C. | 32 | 6 | 22 | −10 | ..... | ..... | 1904 | ..do .... | .....do ..... | 330 |

**WISCONSIN.**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| M. G. Faust ..... | C. | 534 | 4½ | 512 | −75 | ..... | 7 | 1904 | Water. | (L. S.) ..... | 331 |
| .....do ..... | C. | 117 | 4½ | 110 | ..... | ..... | 10 | 1904 | ..do .... | ..... | 332 |
| Chas. L. Green.. | D. | 315 | .... | ..... | ..... | ..... | ..... | 1904 | ..do .... | (L. S.) ..... | 333 |
| Thos. Eagen .... | D. | 155 | .... | ..... | ..... | ..... | ..... | 1904 | ..do .... | (L. S.) ..... | 334 |
| P. Roughen .... | C. | 97 | 5 | 75 | ..... | ..... | ..... | 1904 | ..do .... | ..... | 335 |
| .....do ..... | C. | 95 | 5 | 93 | ..... | ..... | 12 | 1904 | ..do .... | (L.) ..... | 336 |
| .....do ..... | C. | 228 | 5 | 227 | ..... | ..... | 15 | 1904 | ..do .... | (L. S.) ..... | 337 |
| ..... | C. | 800 | 6–5 | ..... | ..... | ..... | ..... | 1887 | ..do .... | (L. S.) ..... | 338 |
| H. G. Gorder.... | C. | 162 | 7¼ | 130 | ..... | ..... | 5 | 1904 | ..do .... | (L. S.) ..... | 339 |
| .....do ..... | C. | 260 | 6¼ | ..... | ..... | ..... | ..... | 1904 | ..do .... | Stratum at 240 feet yields sulphur water. | 340 |
| E. R. Vandervort. | C. | 179 | 6 | ..... | ..... | ..... | ..... | 1904 | ..do .... | (L. S.) ..... | 341 |
| J. Yahnke and F. Sweet. | C. | 35 | 4 | 35 | ..... | ..... | ..... | 1904 | ..do .... | "Good stream of water." | 342 |
| G. H. Fischer and F. Sweet. | C. | 117 | 4 | 116 | − 5 | ..... | ..... | 1904 | ..do .... | (L. S.) ..... | 343 |
| .....do ..... | C. | 41 | 4 | 35 | ..... | ..... | ..... | 1904 | ..do .... | (L.) ..... | 344 |
| .....do ..... | C. | 105 | 4 | 100 | ..... | ..... | ..... | 1904 | ..do .... | ..... | 345 |
| F. Sweet ..... | C. | 23 | 4 | ..... | ..... | ..... | ..... | 1904 | ..do .... | ..... | 346 |
| R. Haase and Wescott. | C. | 87 | .... | 70 | ..... | ..... | ..... | ..... | ..do .... | ..... | 347 |
| G. H. Fischer and M. Hills. | C. | 150 | 4 | 150 | ..... | ..... | ..... | 1904 | ..do .... | ..... | 348 |
| J. J. Faust..... | D. | 300 | 4½ | ..... | −60 | ..... | 3 | 1904 | ..do .... | (S.)..... | 349 |
| H. Jorgensen... | D. | 94 | 4 | ..... | ..... | ..... | 15 | 1904 | ..do .... | (L. S.) ..... | 350 |
| .....do ..... | D. | 98 | 4 | 98 | ..... | ..... | 25 | 1904 | ..do .... | (L. S.) ..... | 351 |
| B. I. Baley & Son | M. | 280 | 6–5¼ | 230 | ..... | ..... | 3 | 1904 | ..do .... | (L. S.) ..... | 352 |
| W. L. Thorne & Co. | C. | 252 | 6 | 200 | ..... | 30 | 250 | 1904 | ..do .... | Water at 71 feet, rose to −2 feet. (L. S.) | 353 |
| H. M. Knaack.. | D. | 190 | 6 | 170 | ..... | 20 | ..... | 1904 | ..do .... | Water from 170 to 190 feet. | 354 |
| J. Yahnke..... | C. | 38 | 4 | 28 | ..... | ..... | ..... | 1904 | ..do .... | Pumps small stream. | 355 |
| John Yahnke and F. Sweet. | C. | 114 | 4 | 107- | −60 | ..... | ..... | 1904 | ..do .... | (L.) ..... | 356 |
| J. Yahnke and M. Hills. | C. | 98 | 4 | ..... | ..... | ..... | ..... | 1904 | ..do .... | ..... | 357 |

**WYOMING.**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| L. J. Craig..... | D. | 2,400 | 13 | ..... | ..... | ..... | ..... | 1904 | Oil .... | Water-bearing bed at 30 and 90 feet. Small showing of oil at 625 feet. | 358 |

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## DETAILED RECORDS.

The detailed reports which follow were selected because they give definite stratigraphic information or information of importance in drilling adjoining wells. While only such records were chosen as appeared to have been kept with care, the Survey does not guarantee their accuracy. Descriptions are given substantially as presented in the original records, although the compiler has taken the liberty to make some changes in nomenclature, such as substituting shale for "soapstone," and to make other modifications in favor of uniformity and conciseness. When the samples suggest an interpretation radically different from the one in the driller's log, both are given, with the former in parentheses. Other interpolations made on the authority of the compiler are also bracketed.

*13. Well near Seaside, Monterey County, Cal.*

[Authority, B. N. Baker, owner.]

| | Feet. |
|---|---|
| Surface soil | 0– 10 |
| Water sand | 10– 40 |
| Quicksand | 40– 60 |
| Gray sand | 60–120 |
| Adobe clay | 120–136 |
| Blue clay | 136–148 |
| Sandy shale | 148–155 |
| Hard shale | 155–156 |
| Blue shale | 156–173 |
| "Chalk rock" | 173–183 |
| Blue shale | 183–240 |
| Hard shale | 240–241 |
| Blue shale | 241–253 |
| Yellow clay and sand | 253–263 |
| Cobblestone, gravel, and water | 263–270 |
| Water sand | 270–303 |
| Blue shale | 303–315 |
| "Chalk rock" | 315–338 |
| Sandy shale | 338–425 |
| Blue clay | 425–441 |
| Sand and shale | 441–468 |
| Blue clay | 468–490 |
| Sand and shale | 490–513 |
| Yellow clay | 513–518 |
| White sand, carrying some water | 518–540 |
| Yellow clay | 540–560 |
| Blue shale | 560–581 |
| Sand and gravel | 581–610 |
| Hard shale; shell | 610–617 |

Last entry is probably incorrect. Water was struck at 610 feet, after piercing shell and going with drill into water sand; flow, 30 gallons a minute.

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*14. Well on Pueblo Lot 146, Point Loma, San Diego County, Cal.*

[Begun August 18, 1900; completed March 18, 1901. Authority, Katherine Tingley, owner.]

[Elevation of mouth of well, 255.88 feet above high tide.]

| | Feet. |
|---|---|
| Surface clay | 0– 3 |
| "Hardpan" | 3– 8 |
| Sandy clay | 8– 30 |
| Water-bearing sand | 30– 40 |
| Sandy shale and dry sand | 40– 60 |
| Sandy shale | 60–100 |
| Sand | 100–106 |
| Dark-blue shale | 106–190 |
| Water-bearing sand | 190–192 |
| Dark-blue shale | 192–200 |
| Water-bearing sand | 200–202 |
| Dark-blue shale | 202–260 |
| Whitish clay | 260–261 |
| Coal | 261–262 |
| "Ore" | 262–265 |
| Water-bearing sand, good water | 265–271 |
| Dark-blue shale | 271–298 |
| Water-bearing sand | 298–300 |
| Dark-blue shale | 300–320 |
| White quartz. } gold colors from panning { | 320–321 |
| Blue granite .. } gold colors from panning { | 321–323 |
| Light-blue shale | 323–350 |
| Alternate shale and sand | 350–360 |
| Light-blue shale | 360–370 |
| Water-bearing sand | 370–372 |
| Light-blue shale | 372–388 |
| Water-bearing gravel and sand | 388–390 |
| Shale, gravel, and clay | 390–400 |

Point Loma is an isolated cretaceous summit, according to the State Mining Bureau, and the above log shows the geologic column of its undisturbed strata. Diameter of well, 6 inches, 0 to 40 feet; 5 inches, 40 to 400 feet. Water level, 253 feet below surface, or 2.88 feet above high tide. Estimated yield, 35,000 gallons daily if all water-bearing strata are used.

*22. Well at Lajunta, Otero County, Colo.*

[Samples furnished by La Junta Oil and Gas Company.]

| | Feet. |
|---|---|
| Clay | 800–1,080 |
| Sandstone and limestone | 1,230–1,290 |
| Light-red sandstone and limestone | 1,300–1,500 |
| Dark-red sandstone—limy | 1,500–1,535 |
| White sandstone | 1,535–1,600 |
| Red sandstone | 1,600–1,612 |
| Red sandstone and gray limestone | 1,612–1,660 |
| Red sandstone and limestone | 1,660–1,703 |

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*42. Well at Belvidere, Boone County, Ill.*

[Begun April 9, 1903; completed May 23, 1903. Authority, H. W. Hambrecht, driller.]

| | Feet. | | |
|---|---|---|---|
| Quicksand | 0 | – | 40 |
| Fine gravel | 40 | – | 90 |
| Coarse gravel | 90 | – | 122.5 |
| Gray limestone | 122.5 | – | 355 |
| St. Peter's sandstone, coarse and honeycombed, water-bearing | 355 | – | 574 |
| Red marl and limestone | 574 | – | 608 |
| Brown limestone | 608 | – | 643 |
| Brown shale | 643 | – | 718 |
| Sandstone—water of good quality | 718 | – | 834 |
| Red marl | 834 | – | 854 |
| Blue shale | 854 | – | 984 |
| White sandstone, honeycombed rock, water-bearing | 984 | – | 1,070 |
| Blue shale | 1,070 | – | 1,168 |
| Postdam sandstone, soft water | 1,168 | – | 1,231 |

Well ended in blue shale. Total depth, 1,231 feet. Ten-inch drive-pipe, 0 to 125 feet; diameter of hole 8 inches from 125 to 608 feet; 6¼ inches from 608 to 1,231 feet.

*46. Well at Naperville, Dupage County, Ill.*

[Begun August 31, 1903; completed January 19, 1904. Authority, H. W. Hambrecht, driller.]

| | Feet. | | |
|---|---|---|---|
| Black soil | 0 | – | 4 |
| Sand and gravel | 4 | – | 10 |
| Blue shale | 10 | – | 18 |
| Loose rolling rock | 18 | – | 21 |
| White limestone | 21 | – | 237 |
| Blue shale | 237 | – | 320 |
| White limestone | 320 | – | 646 |
| St. Peter's sandstone; water, hard and soft in streaks | 646 | – | 792 |
| Blue shale | 792 | – | 836 |
| Brown limestone | 836 | – | 950 |
| Blue shale | 950 | – | 1,152 |
| Gray limestone—water-bearing rock full of crevices | 1,152 | – | 1,425 |

Ten-inch drive pipe from 0 to 117,5 feet; diameter of hole, 8 inches from 117.5 to 836 feet; 6¼ inches from 836 to 1,425 feet.

*47. Well in SE. ¼ of NW. ¼ sec. 32, T. 15 N. (1½ miles west of Kewanee), Henry County, Ill.*

[Begun September 9, 1904, completed November 21, 1904. Record and samples furnished by L. Nichols, driller. Geologic divisions made by E. O. Ulrich.]

| | Feet. | | |
|---|---|---|---|
| Yellow clay | 0 | – | 10 |
| Yellow clay, sandy | 10 | – | 20 |
| Lower Pennsylvania coal measures: | | | |
| Blue sandy clay | 20 | – | 36 |
| Soft drab shale | 36 | – | 85 |
| Coal | 85 | – | 86.5 |
| Soft drab shale | 86.5 | – | 92.5 |
| Hard gray sandstone | 92.5 | – | 93.5 |
| Soft drab shale | 93.5 | – | 172 |
| Coal and shale | 172 | – | 184 |
| Coal | 184 | – | 187 |

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| | Feet. | | |
|---|---|---|---|
| Lower Pennsylvania coal measures—Continued. | | | |
| Soft dark shale | 187 | – | 202 |
| Hard dark sandstone | 202 | – | 202.5 |
| Soft gray shale mixed with lime | 202.5 | – | 238 |
| Soft black shale; with pyrite 282–301 | 238 | – | 308 |
| Gray sandy shale | 308 | – | 322 |
| Gray sandy limestone | 322 | – | 352 |
| Devonian and Silurian limestone: | | | |
| Hard gray limestone | 352 | – | 650 |
| Light-blue limestone | 650 | – | 670 |
| White limestone | 670 | – | 730 |
| Gray limestone | 730 | – | 760 |
| Maquoketa: | | | |
| Light-green shale | 760 | – | 833 |
| Hard gray limestone | 833 | – | 850 |
| Hard light-green shale | 850 | – | 915 |
| Hard brown shale | 915 | – | 940 |
| Hard drab shale | 940 | – | 949 |
| Galena limestone: | | | |
| Dark-brown limestone | 949 | – | 970 |
| Gray limestone | 970 | – | 1,030 |
| Brown and white limestone | 1,030 | – | 1,050 |
| Brown limestone | 1,050 | – | 1,073 |

Rig used, pole tools. Diameter of well, 12 inches 0 to 174 feet; 10½ inches 174 to 352 feet; 8⅝ inches 352 to 954 feet; 6 inches from 954 to 1,073 feet. Hole practically dry to 475 feet, where water rose to within 300 feet of mouth of well. Water fresh, no great amount. Main supply from 954 to 1,073 feet. Well pumps 80 gallons a minute.

*52. Well at Streator, Lasalle County, Ill.*

[Begun September 5, 1902; completed November 15, 1902. Authority, H. W. Hambrecht, driller.]

| | Feet. | | |
|---|---|---|---|
| Yellow clay | 0 | – | 5 |
| Shale | 5 | – | 8 |
| Coal | 9 | – | 13.5 |
| Shale | 13.5 | – | 15 |
| Brick and tile clay | 15 | – | 20 |
| Blue shale | 20 | – | 90 |
| Blue and brown shale | 90 | – | 95 |
| Coal, good quality | 95 | – | 99.5 |
| Blue shale | 99.5 | – | 172.5 |
| Brown and blue shale | 172.5 | – | 185 |
| Coal, best | 185 | – | 187 |
| Brick and tile clay | 187 | – | 195 |
| White limestone | 195 | – | 385 |
| St. Peter's sandstone; water in lower part not good | 385 | – | 596 |
| Blue shale | 596 | – | 620 |
| Brown limestone; very good water | 620 | – | 706 |
| Madison sandstone; slightly salty water | 706 | – | 834 |
| Brown limestone; soft water | 834 | – | 1,056 |
| Sandstone; water | 1,056 | – | 1,096 |
| Limestone | 1,096 | – | 1,115 |

Eight-inch pipe from 0 to 195 feet; 6-inch pipe from 0 to 620 feet; 6-inch hole from 620 to 1,115 feet.



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*62. Well No. 1, on G. S. Whitehair farm, in SE. ¼ of SE. ¼ sec. 24 (4 miles SE. of Albany), Delaware County, Ind.*

[Begun October 11, 1904, completed October 31, 1904. Authority, William Jameson, driller.]

| | Feet. | |
|---|---|---|
| Soft black soil | 0– | 10 |
| Hard dark limestone | 10– | 45 |
| Soft red shale | 45– | 60 |
| Gray limestone of varying hardness | 60– | 200 |
| Soft shale (calcareous) | 200– | 220 |
| Hard blue limestone | 220– | 260 |
| Soft light shale | 260– | 280 |
| Hard dark limestone and shale | 280– | 300 |
| Hard blue limestone | 300– | 340 |
| Soft light shale | 340– | 500 |
| Soft brown shale | 500– | 600 |
| Soft light shale | 600– | 700 |
| Soft dark shale | 700– | 800 |
| Soft brown shale | 800– | 950 |
| Trenton limestone | 950– | 1,260 |

Some gas at top of Trenton. Well finished at 1,262 feet with little show for oil. Shot with 200 quarts of glycerine. Diameter of well, 8 inches from 65 to 340 feet; 6¼ inches from 340 to 1,262 feet. Casing inserted at 340 feet. Principal water-bearing strata between 30 and 320 feet.

*64. Well No. 5, on the Hoppis heirs' farm, in sec. 24, T. 12 E. (one-half mile east of Redkey), Jay County, Ind.*

[Begun October 10, 1904, completed November 5, 1904. Authority, Bert Gilbert, driller.]

| | Feet. | |
|---|---|---|
| Soft brown clay | 0– | 40 |
| Soft blue clay | 0– | 100 |
| Hard yellow limestone | 100– | 120 |
| Hard gray limestone | 120– | 180 |
| Soft gray shale, "brake" | 180– | 240 |
| Hard gray limestone | 240– | 260 |
| Soft gray shale, "brake" | 260– | 300 |
| Hard gray limestone | 300– | 320 |
| Soft gray shale (brownish, 800–840) | 320– | 960 |
| Trenton limestone; gas, pay 960–980; oil sand, 1,360–1,385 | 960– | 1,385 |

Principal water stratum in limestone at depth of 153 feet. Amount of oil obtained, 5 barrels.

*69. Well at Cherokee State Hospital, in sec. 28, T. 92, R. 40 (1½ miles NW. of Cherokee), Cherokee County, Iowa.*

[Completed February 24, 1902. Authority, Cherokee State Hospital.]

| | Feet. | |
|---|---|---|
| Loam | 0– | 4 |
| Yellow clay | 4– | 60 |
| Blue clay | 60– | 240 |
| Quicksand; water | 240– | 255 |
| Gravel; water | 255– | 260 |
| Quicksand; water | 260– | 270 |
| Blue clay | 270– | 355 |

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| | Feet. |
|---|---|
| Sandstone; water | 355– 375 |
| Shale | 375– 385 |
| Pink shale | 385– 400 |
| Gravel; water | 400– 405 |
| Gray shale | 405– 410 |
| Red shale | 410– 430 |
| Gray limestone; water between 430 and 435 | 430– 450 |
| Gray shale | 450– 470 |
| Gray limestone; water between 470 and 475 | 470– 480 |
| Shale | 480– 490 |
| Limestone | 490– 505 |
| Sandstone | 505– 510 |
| Shale | 510– 525 |
| Sandstone; water | 525– 535 |
| Limestone; water rose 30 feet from crevice in rock between 725 and 735 feet | 535– 965 |
| Shale | 965–1,015 |
| Sandstone; at 1,075 feet water rose 970 feet | 1,015–1,095 |
| Shale | 1,095–1,100 |
| Gypsum | 1,100–1,120 |

Diameter of well, 12 and 9 inches; 6-inch pump casing 500 feet down. Depth of principal source of water, 1,120 feet. Water rises to within 206 feet of mouth of well. Yield, 100,000 gallons in twenty-four hours.

*70. Well at Burlington, Des Moines County, Iowa.*

[Begun August 22, 1904; completed October 12, 1904. Authority, R. J. Johnston, driller.]

| | Feet. |
|---|---|
| Artificial filling | 0– 10 |
| Yellow clay | 10– 20 |
| Blue clay | 20– 60 |
| Sand | 60– 66 |
| Blue clay | 66– 72 |
| Soft limestone | 72– 75 |
| Soft gray shale | 75– 85 |
| Soft blue shale | 85–154 |
| Soft black shale | 154–160 |
| Gray shale | 160–190 |
| Soft dark shale | 190–260 |
| Soft gray shale | 260–280 |
| Hard blue limestone | 280–305 |
| Hard gray limestone | 305–325 |
| Soft gray shale (limestone) | 325–335 |
| Hard gray limestone | 335–355 |
| Hard red "granite" (limestone containing pyrite) | 355–400 |
| Soft blue limestone | 400–410 |
| Soft red limestone | 410–425 |
| White "magnesia" (clayey limestone) | 425–435 |
| Soft "water rock" (no samples below 430) | 435–507 |

Rig used, Keystone driller. Diameter, 5⅛ inches from 0 to 507 feet. Length of casing, 76 feet. Main water supply from 435 to 507 feet. Flows 45 gallons per minute. Pressure, 16½ pounds.

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*71. Well at Davenport, Scott County, Iowa.*

[Begun March 10; completed July 8, 1904. Authority, H. W. Hambrecht, driller.]

| | Feet. |
|---|---|
| Surface sand | 0– 24 |
| Blue shale | 24– 89 |
| Black shale | 89– 90 |
| Blue shale | 90– 110 |
| Loose rock | 110– 113 |
| Brown limestone | 113– 270 |
| Blue shale | 270– 275 |
| Limestone | 275– 418 |
| White shale | 418– 644 |
| Brown limestone; flow from crevice, about 80 gallons a minute | 644– 970 |
| Blue shale | 970– 996 |
| Sandstone, St. Peter's; flow increased to 210 gallons a minute | 996–1,050 |
| Brown limestone; flow increased to 310 gallons a minute | 1,050–1,300 |

Ten-inch casing from 0 to 110 feet, 8-inch casing from 0 to 120 feet, 8-inch hole from 120 to 1,300 feet.

*78. Well at Horace (4 miles east of the Kansas-Colorado State line), Greeley County, Kans.*

[Begun February 19, 1901; completed November 26, 1901. Authority, E. Fisher, engineer B. & B.]

| | Feet. |
|---|---|
| Cemented gravel mixed with clay and lime | 0– 55 |
| Clay, gravel, and lime mixed | 55– 100 |
| Gray shale | 100– 550 |
| White limestone | 550– 620 |
| Brown shale; water at 825 rose 400 feet | 620–1,050 |
| Sandstone, more or less broken; top of first Dakota | 1,050–1,095 |
| Gray sandstone | 1,095–1,110 |
| Reddish brown sandstone, broken, very much so, 1,130–1,148 | 1,110–1,148 |
| Sandstone; bottom of first Dakota | 1,148–1,160 |
| Shale | 1,160–1,250 |
| Reddish brown sandstone, more or less broken; second Dakota water rose 800 feet from 1,325 feet | 1,250–1,325 |
| Shale | 1,325–1,370 |

Water obtained from Dakota sandstone. In pumping the well for several months the water which originally stood at a level of about 830 feet below the ground line was lowered gradually to about 1,000 feet below the ground line, and the difficulty in pumping the limited amount of water (about 30 gallons a minute) was so great that the well was abandoned.

*80. Well No. 3 on the Robb farm, SE. ¼ of SE. ¼ of T. 25, R. 12 (near Neal), Greenwood County, Kans.*

[Begun October 8, 1904; completed November 12, 1904. Authority, F. R. Gammon, owner.]

| | Feet. |
|---|---|
| Soil and clay | 0– 20 |
| Gravel | 20– 30 |
| Blue clay | 30– 60 |
| Limestone | 60– 80 |
| Blue shale | 80–103 |
| Limestone | 103–126 |
| Blue shale | 126–141 |

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| | Feet. |
|---|---|
| Red shale | 141–154 |
| Blue shale | 154–171 |
| Limestone | 171–187 |
| Shale | 187–234 |
| Limestone | 234–238 |
| Shale | 238–285 |
| Sandy shale | 285–308 |
| Blue shale | 308–345 |
| Limestone | 345–348 |
| Shale | 348–350 |
| Limestone | 350–363 |
| Sandstone; water | 363–381 |
| Shale | 381–386 |
| Blue shale; 8¼ inch casing | 386–505 |
| Limestone | 505–550 |
| Soft limestone; had to put in water to drill | 550–560 |
| Limestone; 15 feet soft | 560–596 |
| Hard limestone | 596–645 |
| Limestone | 645–655 |
| Blue shale | 655–675 |
| Limestone | 675–685 |
| Sandy shale | 685–700 |
| Blue shale | 700–792 |
| Very hard limestone | 792–812 |
| Blue shale | 812–842 |
| Limestone; water | 842–882 |
| Sandstone | 882–902 |
| Limestone; strong odor of oil | 902–920 |
| Black shale | 920–927 |
| Limestone | 927–932 |
| Oil sand | 932 |

*83. Well No. 1, on the Logan farm, W. ½ SW. ¼ sec. 27, T. 33, R. 15 (9 miles south of Independence), Montgomery County, Kans.*

[Begun April 25, 1904; completed May 13, 1904. Authority, A. J. Yoke, owner.]

| | Feet. |
|---|---|
| Surface soil | 0– 15 |
| Shale and lime shell | 15–120 |
| Limestone | 120–135 |
| Dark shale | 135–140 |
| Gritty shale | 140–165 |
| Limestone | 165–175 |
| Shale (limy) | 175–220 |
| Limestone | 220–260 |
| Sandstone; water and gas | 260–275 |
| Shale | 275–330 |
| Limestone | 330–335 |
| Shale (limy) | 335–465 |
| Limestone | 465–495 |
| Shale (limy) | 495–525 |
| Limestone | 525–535 |
| Shale | 535–540 |
| Limestone | 540–555 |

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| | Feet. |
|---|---|
| Shale | 555– 585 |
| Sandstone; water | 585– 640 |
| Gritty shale | 640– 680 |
| Limestone | 680– 705 |
| Black shale | 705– 710 |
| Shale (limy) | 710– 725 |
| Gray sand; oil | 725– 730 |
| Gritty shale | 730– 740 |
| Gray sand | 740– 760 |
| Black shale | 760– 783 |
| "Big lime" | 783– 818 |
| Black shale | 818– 825 |
| Limestone | 825– 853 |
| Shale, gas and water | 853– 855 |
| Limestone | 855– 875 |
| Black shale | 875– 885 |
| Sandstone; water | 885– 895 |
| Shale (limy) | 895– 955 |
| Dark shale | 955– 965 |
| Gritty shale (limy) | 960– 990 |
| Shale | 990–1,005 |
| Shale (limy) | 1,005–1,080 |
| Dark limestone | 1,080–1,115 |
| Sand; gas | 1,115–1,118 |
| Hard gritty shale | 1,118–1,142 |
| Sandstone; gas | 1,142–1,160 |

Yield first twenty-four hours, 18,000,000 feet; initial pressure, 480 pounds. Forty-one feet of 8¼-inch casing, 950 feet of 6¼-inch casing.

*84. Well No. 22, on the S. Smith farm, SE. ¼ of SE. ¼ sec. 10, T. 27, R. 18 (2 miles NE. of Chanute), Neosho County, Kans.*

[Begun November 9; completed November 27, 1904. Authority, J. F. Allen, field manager for I. N. Knapp.]

| | Feet. |
|---|---|
| Surface soil | 0– 20 |
| Brown gravel; fresh water | 20– 30 |
| Hard gray limestone | 30– 56 |
| Sandstone | 56– 61 |
| Hard gray limestone | 61– 65 |
| Soft gray shale | 65– 70 |
| Hard gray limestone | 70– 75 |
| Soft gray sandstone | 75– 80 |
| Soft gray limestone | 80–115 |
| Soft gray shale (limy) | 115–125 |
| Soft gray limestone; 4 barrels water an hour at 128 feet | 125–130 |
| Hard gray limestone | 130–142 |
| Soft gray shale (limy) | 142–320 |
| Soft light-gray limestone | 320–335 |
| Soft gray shale (limy) | 335–370 |
| Gray sandstone; salt water and gas; hole filled up 200 feet | 370–385 |
| Soft gray shale (limy) | 385–400 |
| Soft gray limestone | 400–420 |
| Shale | 420–428 |

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| | Feet. |
|---|---|
| Hard gray limestone | 428–458 |
| Soft gray shale (limy) | 458–490 |
| Hard gray limestone | 490–513 |
| Hard black shale (limy); water, 40 barrels an hour | 513–521 |
| Hard gray limestone | 521–528 |
| Soft gray shale (limy) | 528–715 |
| Soft gray shale (sandy); top of sand, showing of oil | 715–720 |
| Soft gray sandstone and shale (limy) | 720–728 |
| Sandstone; oil sand, 22 feet of pay at bottom | 728–752 |

Yield, 4 or 5 barrels a day. Length of casing, 623 feet; diameter, 5 inches.

*122. Well 1 mile north of Bay St. Louis, Hancock County, Miss.*

[Begun October 29; completed November 20, 1904. Authority, John L. Ford, driller.]

| | Feet. |
|---|---|
| Blue sandy clay | 0– 10 |
| White sand | 10– 60 |
| Yellow sand | 60– 95 |
| White sand and gravel | 95–145 |
| Green clay | 145–160 |
| Gray sand | 160–220 |
| Green clay | 220–350 |
| Gray sand | 350–370 |
| Green clay | 370–650 |
| Water sand; flows 50 gallons a minute | 650–690 |
| Blue clay | 690–818 |
| Water sand; flows 225 gallons a minute | 818–897 |

Diameter of well, 3 inches.

*126. Well 1½ miles northwest of Moss Point, Jackson County, Miss.*

[Begun October 3, 1904; completed October 12, 1904. Authority, John L. Ford, driller.]

| | Feet. |
|---|---|
| Hard yellow clay (sandy) | 0– 20 |
| Yellow sand | 20– 35 |
| Clay (sandy, variegated) | 35– 50 |
| Sand (fine white) | 50–100 |
| Sand (coarse, white) | 100–140 |
| Clay (sandy) | 140–210 |
| Sand (fine white) | 210–220 |
| Clay | 220–370 |
| Sand (fine, white) | 370–390 |
| Clay | 390–710 |
| Sand (fine gray) | 710–790 |
| Clay | 790 |

Main water supply, 770 to 790 feet. Yield, 135 gallons per minute.

*127. Well at Moberly, Randolph County, Mo.*

[Authority, A. P. Phillips, driller and manager.]

| | Feet. |
|---|---|
| Clay and quicksand | 0–115 |
| Blue sandstone | 115–127 |
| Blue and white sandstone | 127–132 |
| Gray sandstone | 132–137 |
| Blue flint | 137–146 |

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| | Feet. |
|---|---|
| Blue and white flint | 146–154 |
| Yellow flint | 154–160 |
| Yellow sandstone | 160–170 |
| Hard white sandstone | 170–178 |
| Gray sandstone | 178–186 |
| Gray sandstone and white flint | 186–191 |
| Yellow sandstone | 191–202 |
| Hard white flint | 202–210 |
| Yellow flint | 210–218 |
| Blue flint | 218–226 |
| Yellow flint | 226–230 |
| Blue and white flint | 230–250 |
| White flint | 250–260 |
| Blue flint | 260–263 |
| White and brown flint | 263–266 |
| Brown flint | 266–269 |
| White sandstone | 269–272 |
| Blue sandstone | 272–275 |
| Blue and white sandstone | 275–278 |
| White sandstone | 278–281 |
| Light-gray sandstone | 281–289 |
| Light-brown sandstone | 289–290 |
| Dark-brown sandstone | 290–320 |
| Gray sandstone | 320–345 |
| White sandstone | 345–355 |
| White and yellow sandstone | 355–380 |
| Gray sandstone | 380–430 |
| Dark-gray sandstone | 430–447 |
| Green shale | 447–450 |
| Dark coarse sandstone | 450–460 |
| Dark-gray sandstone | 460–470 |
| Gray sandstone | 470–480 |
| Green shale and gray sandstone | 480–490 |
| Light and dark sandstone | 490–510 |
| Dark-gray sandstone | 510–520 |
| Black sandstone | 520–560 |
| Brown sandstone | 560–570 |
| Dark-gray sandstone | 570–580 |
| Gray sandstone | 580–590 |
| White limestone | 590–600 |
| Dark-gray sandstone | 600–607 |
| Green shale | 607–612 |
| Gray sandstone | 612–632 |
| White gravel, like glass sand; great quantity of good water | 632–685 |
| Gray sandstone | 685–693 |
| Green sandstone | 693–705 |
| White and gray sandstone | 705–709 |
| Gray sandstone | 709–722 |
| Brown sandstone | 722–772 |
| Light-brown sandstone | 772–802 |
| Gray sandstone | 802–832 |
| Brown sandstone | 832–840 |
| Light-brown sandstone | 840–850 |

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| | Feet. |
|---|---|
| Clear white water sand; salt water at 870 feet | 850– 870 |
| Light-gray sandstone | 870– 960 |
| Brown sandstone | 960–1,020 |
| Dark-brown sandstone | 1,020–1,045 |
| Fine brown sandstone | 1,045–1,100 |
| Black and brown sandstone | 1,100–1,115 |
| Light-gray sandstone | 1,115–1,150 |
| Gray sandstone | 1,150–1,170 |
| White and gray sandstone; magnesia water at 1,180 feet | 1,170–1,190 |
| Yellow and white sandstone | 1,190–1,200 |
| Dark-gray sandstone | 1,200–1,210 |
| Black and white sandstone | 1,210–1,215 |
| Gray sandstone; very salty water at 1,215 feet | 1,215–1,220 |
| Blue and white flint | 1,220–1,225 |
| Crevice and pebbles | 1,225–1,230 |
| Blue and gray sandstone | 1,230–1,240 |
| Fine white sandstone | 1,240–1,260 |
| White flint | 1,260–1,290 |
| Blue and gray sandstone | 1,290–1,300 |
| Dark-gray sandstone | 1,300–1,330 |
| Gray sandstone | 1,330–1,440 |
| Yellow and white sandstone | 1,440–1,450 |
| Blue sandstone | 1,450–1,460 |
| Fine white sandstone | 1,460–1,480 |
| Black and white sandstone | 1,480–1,500 |
| Brown sandstone | 1,500–1,560 |
| Dark-red sandstone | 1,560–1,600 |
| Light-brown sandstone | 1,600–1,660 |
| Gray sandstone | 1,660–1,690 |
| Brown sandstone | 1,690–1,705 |
| Black and white sandstone | 1,705–1,965 |
| Dark-gray sandstone | 1,965–2,000 |
| Gray sandstone | 2,000–2,100 |
| Gray shale | 2,100 |

Main water supply at 632 feet. Water rose to within 70 feet of mouth of well.

*129. Well on northwest corner of Vanderenter and Forrest Park Boulevard, St. Louis, Mo.*

[Begun October 26, completed December 7, 1904. Authority, E. D. Meloy, driller.]

| | Feet. |
|---|---|
| Filled ground | 0– 20 |
| Soft gray clay | 20– 40 |
| Sand and gravel | 40– 60 |
| Hard gray limestone (shaly); a little water | 60– 80 |
| Soft brown limestone | 80–100 |
| Hard brown limestone | 100–120 |
| Soft gray limestone; water 140–160 and 185–210 | 120–240 |
| Soft gray shale | 240–260 |
| Hard gray limestone | 260–265 |
| Soft gray limestone and shale | 265–280 |
| Gray limestone; showing of oil 280–290 and 305–325 | 280–460 |
| Very hard gray limestone and chert | 460–470 |
| Hard gray limestone | 470–485 |
| Soft gray shale | 485–490 |

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| | Feet. |
|---|---|
| Hard gray limestone | 490–510 |
| Soft dark-red shale; showing of oil | 510–530 |
| Hard gray limestone | 530–565 |
| Hard gray limestone and shale; bad caves | 565–600 |
| Soft black shale; a little oil | 600–620 |
| Soft brown limestone, Trenton; a little oil | 620–650 |

"From 490 to 600 feet is probably Kinderhook, from 600 to 620 feet is probably Devonian Ohio shale."—E. O. Ulrich.

Well yields a small amount of gas.

*141. Well 1½ miles northeast of Pleasantville, Atlantic County, N. J.*

[Begun January 27, 1903, completed January 31, 1903. Authority, E. E. Lanpher, assistant civil engineer, Atlantic City water department.]

| Elevation of mouth of well, 10 feet A. T. | Feet. |
|---|---|
| Yellow sand and gravel | 0– 18 |
| Gravel mixed with clay | 18– 23 |
| Soft blue clay | 23– 29 |
| Yellow sand and wood | 29– 35 |
| White sand; water-bearing | 35– 55 |
| Yellow sand and gravel; water-bearing | 55–100 |
| Hard light-gray clay and gravel | 100–120 |
| Soft gray sand and clay | 120–138 |
| Red and white sand; water flowed over casing 2 feet above ground | 138–158 |
| Coarse and fine gray sand | 158–230 |
| Soft gray sand and clay | 230–240 |
| Coarse gray sand | 240–250 |
| Soft greenish-gray marl and sand, growing harder toward bottom of bed | 250–310 |
| Hard gray clay | 310–320 |

Well discontinued at 320 feet in a rather soft gray sandy clay, and casing withdrawn. Rig used, jet. This was a 4½-inch test well at the Absecon Pumping Station of the water department of Atlantic City. The location is the same as that of the United States Meteorological Station, Pleasantville, N. J. The well was never pumped. Within one-fourth mile of this test well are eleven 10-inch and one 4½-inch wells, yielding about 4,000,000 gallons a day and sunk to about −95 elevation, and one 18-inch well yielding about 700,000 gallons a day, sunk to about −190 elevation. All these wells belong to the water department of Atlantic City and are pumped by compressed air.

*157. Well one-half mile west of Atlantic Highlands, Monmouth County, N. J.*

[Begun October 1, 1904, completed November 1, 1904. Authority, F. E. Price, superintendent, Atlantic Highlands Waterworks.]

| | Feet. |
|---|---|
| Red sand and clay | 0– 8 |
| Bluish sand and marl | 8– 16 |
| Gray sand | 16– 30 |
| Yellowish sand and wood | 30– 40 |
| Light-gray sand; wood between 137 and 157 feet | 40–157 |
| Marl (dark gray) | 157–244 |
| Marl (fine gray micaceous sand) | 244–272 |
| Dark-gray sand | 272–292 |
| Marl (dark gray) | 292–346 |

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| | Feet. |
|---|---|
| Sand and clay (white and greenish) | 346–365 |
| Sandy clay (fine light-gray micaceous sand) | 365–392 |
| Gray sand | 392–452 |

Rig used, jet. Diameter of well, 4½ inches. Length of casing, 412 feet. Strainer inserted at 412 feet. Well flows 20 gallons a minute and yields 125 gallons by pumping.

*174. Well No. 1, Group B, Solway Process Company, Tully, Onondaga County, N. Y.*

[Produced brine October 30, 1890. Authority, Solway Process Company.]

| Elevation of floor line, 509 feet A. T. (Syracuse datum.) | Feet. |
|---|---|
| Drift | 0– 12 |
| Hamilton: | |
| Soft gray shale | 12– 192 |
| Blue shale | 192– 252 |
| Bluish-gray shale | 252– 302 |
| Gray shale | 302– 352 |
| Soft gray shale | 352– 422 |
| Very soft gray shale | 422– 610 |
| Blue shale | 610– 680 |
| Onondaga or Corniferous limestone | 680– 750 |
| Oriskany sandstone | 750– 770 |
| Salina or Lower Helderberg?: | |
| Blue-black magnesian limestone | 770– 795 |
| Gray gypseous limestone | 795– 885 |
| Blue-black limestone | 885– 895 |
| Salina: | |
| Gray magnesian limestone | 895–1,025 |
| Gray gypseous shale | 1,025–1,090 |
| Greenish limestone | 1,090–1,135 |
| Black gypseous shale | 1,135–1,175 |
| Salt | 1,175–1,493 |
| Shale at 1,493. | |

*201. Well in South Lima district, Findlay, Hancock County, Ohio.*

[Begun October 10, 1904, completed October 23, 1904. Authority, J. E. Finnerty.]

| | Feet. |
|---|---|
| Surface soil | 0– 25 |
| Hard gray limestone; good drinking water between 34 and 50 feet, and black sulphurous water between 50 and 60 feet | 25–165 |
| Dark-blue shale | 165–170 |
| Dark-blue limestone | 170–175 |
| Hard gray limestone | 175–180 |
| Soft gray shale | 180–185 |
| Hard light-gray and brown limestone | 185–235 |
| Hard dark-gray shale | 235–245 |
| Hard light-brown limestone | 245–260 |
| Soft light-blue shale | 260–310 |
| Soft red shale | 310–355 |
| Soft blue shale | 355–540 |
| Hard blue limestone | 540–560 |
| Hard blue shale | 560–600 |
| Soft blue shale | 600–950 |

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| | Feet. |
|---|---|
| Soft brown shale | 950–1,040 |
| Soft black shale—harder last 15 feet | 1,040–1,115 |
| Trenton limestone | 1,115–1,158 |

Twenty-five feet 8¼-inch drive pipe. Diameter of well, 6¼ inches from 25 to 1,158 feet. Length of casing, 310 feet to top of red Medina shale. After casing was seated and found tight, drillers made from 115 to 130 feet a tour, and no water was found until well was finished and shot with 100 quarts of glycerine. After the shot there was more salt water than could be pumped, so the well was plugged and casing pulled. Well was drilled for gas. Small amount obtained.

*224. Well No. 2 on Mrs. L. Dienst farm, SW. ¼ SW. ¼ sec. 6, T. 4, R. 11 E. (one-fourth mile east of Portage) Wood County, Ohio.*

[Begun November 1, completed November 19, 1904. Samples furnished by G. F. Munn, owner.]

| | Feet. |
|---|---|
| Surface soil | 0– 20 |
| Gray limestone | 20– 200 |
| Blue shale | 200– 220 |
| Gray limestone | 220– 260 |
| Brownish limestone and pyrite | 260– 280 |
| Blue shale | 280– 340 |
| Dark red shale | 340– 360 |
| Sample missing | 360– 380 |
| Blue shale | 380– 780 |
| Black shale | 780– 920 |
| Brownish gray limestone | 920– 940 |
| Reddish shale | 940– 960 |
| Gray limestone | 960–1,040 |
| Black shale; oil sand at 1,102 feet | 1,040–1,120 |
| Brownish-gray limestone with pyrite at 1,180 feet | 1,120–1,262 |

Diameter of well, 8¼ inches from 0 to 300 feet, 6¼ inches from 300 to 1,262 feet. Length of casing, 300 feet. Well was shot with 120 quarts of glycerine. Amount of oil obtained, 5 barrels a day. Gas pressure, 50 pounds.

*243. Well No. 6 on the L. C. Grimm farm, 1¾ miles northeast of Higbee, Greene County, Pa.*

[Begun June 6, completed August 15, 1904. Authority, J. J. Reed, driller.]

| | Feet. |
|---|---|
| Pittsburg coal | 920– 927 |
| Big Dunkard sand | 1,422–1,517 |
| Gas sand | 1,705–1,760 |
| Salt sand | 1,770–1,960 |
| Big lime | 2,026–2,100 |
| Big Injun sand | 2,115–2,345 |
| Thirty-foot sand | 2,745–2,805 |
| Fifty-foot sand | 2,855–2,910 |
| Gordon sand | 2,969–2,994 |
| Shale | 2,994–3,005 |
| Fourth sand | 3,005–3,076 |

Yield of oil: 10 barrels.

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*244. Well No. 1 on the John Lewis farm, Morris Township, Greene County, Pa.*

[Begun October 13, completed December 15, 1904. Authority, H. A. Reardon, driller.]

| | Feet. |
|---|---|
| Soft yellow clay | 0– 16 |
| Soft black shale | 16– 180 |
| Soft white sandstone | 180– 195 |
| Soft black shale | 195– 300 |
| Hard white limestone | 300– 400 |
| Soft black shale | 400– 550 |
| Hard white sandstone | 550– 575 |
| Soft black shale | 575– 600 |
| Hard white sandstone | 600– 635 |
| Coal, Waynesburg | 635– 640 |
| Hard white limestone | 640– 835 |
| Coal, Mapletown | 835– 840 |
| Hard white limestone | 840– 935 |
| Coal, Pittsburg—cable measurement | 935– 945 |
| Hard white limestone | 945–1,045 |
| Soft red shale | 1,045–1,100 |
| Hard white limestone | 1,100–1,200 |
| Soft black shale | 1,200–1,335 |
| Hard white sandstone—Little Dunkard sand | 1,335–1,350 |
| Soft black shale | 1,350–1,450 |
| Hard white sandstone—Big Dunkard sand | 1,450–1,510 |
| Soft white shale | 1,510, 1,560 |
| Hard white sandstone | 1,560–1,585 |
| Soft black shale | 1,585–1,685 |
| Soft porous white sandstone—Gas sand | 1,685–1,770 |
| Soft black shale | 1,770–1,802 |
| Hard white sandstone—Salt sand | 1,802–1,910 |
| Soft black shale | 1,910–2,080 |
| Hard white limestone—Big lime | 2,080–2,135 |
| Hard white sandstone—Big Injun | 2,135–2,385 |
| Soft white shale | 2,385–2,705 |
| Hard white sandstone—Thirty-foot sand | 2,705–2,735 |
| Soft black shale | 2,735–2,850 |
| Hard white sandstone—Fifty-foot sand | 2,850–2,900 |
| Soft white shale | 2,900–2,930 |
| Hard white sandstone—Gordon sand—gas at 2,940 | 2,930–2,965 |

Well produces gas. Diameter of casing, 13 inches from 0 to 16 feet, 10 inches from 16 to 200 feet, 8 inches from 200 to 1,590 feet, 6 inches from 1,595 to 2,145 feet.

*254. Well No. 11 on the Adams farm in the Grand Valley oil field, 2 miles east of Grand Valley, Eldred Township, Warren County, Pa.*

[Begun July 25, completed August 11, 1900. Authority, Josiah G. Winger, contractor.]

| | Feet. |
|---|---|
| Soft yellow subsoil; conductor hole 16 inches in diameter | 0– 22 |
| Soft shale and sandstone with little change in the beds; end of 8-inch hole. | 22–308 |
| Soft black shale | 308–550 |
| Soft light-gray sandstone; Second sand; no showing of oil, no salt water | 550–580 |
| Soft blue shale | 580–733 |

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| | Feet. |
|---|---|
| Hard reddish-brown sand; Third sand. This stratum overlies the oil stratum | 733–740 |
| Hard light-gray sandstone; oil and gas | 740–750 |
| Hard white sandstone; salt water in small quantity | 750–775 |
| Soft light-gray sandstone; Second pay or Newton sand | 775–785 |
| Hard black shale | 785–817 |

This well compares favorably with many others drilled on this good stretch of territory. Thickness of the Third Sand varies from 45 to 60 feet. Wells are producing from 15 to 20 barrels a month that were drilled thirty-three years ago and have been pumped steadily ever since. This lease is known as the "Dunderdale" lease. It includes the Dunderdale farm, Adams, Grandon, and Reno land. A well designated in Carl's Geology as the "Atlas" well was drilled within half a mile of this property in 1865 (1867?). No paying wells have been found near the "Atlas," which produced 15 barrels a day; 1,800 in all.

Diameter of well, 5⅝ inches from 0 to 308 feet; length of casing, 308 feet.

*257. Well No. 2 on the M. Cartwright farm, Newton Pool, 2¼ miles northeast of Grand Valley, in Eldred Township, Warren County, Pa.*

[Completed September 7, 1894. Authority, Josiah G. Winger, contractor.]

| | Feet. |
|---|---|
| Clay subsoil; conductor hole 16 inches in diameter | 0– 12 |
| Shale and sandstone; end of 8-inch hole and end of casing. This section includes first bed of shale, fresh-water sand, second bed of shale, and salt-water sand. The last sand in the 8-inch hole is the Second sand "gravel bed." The gravel bed is 10 feet thick and contains oil and salt water | 12–275 |
| Soft black shale; a shell 80 or 90 feet above the Third sand is scarcely perceptible in this field, but farther southwest is 20 feet thick and oil-bearing | 275–404 |
| Hard coarse white sandstone; Third sand. This sandstone is flooded with sweet water, which rose 300 feet in the well | 404–430 |
| Hard black shale, separating sweet from salt water strata | 430–433 |
| Hard pebbly white sandstone; salt water in large quantities | 433–447 |
| Medium hard gray pebbly sandstone—"Gas sand" | 447–449 |
| Soft light gray, coarse-grained sandstone; pay stratum of the Third Sand. | 449–462 |
| Hard black shale | 462–477.5 |

In this well the sand is the best yet found. The well is the best producer in the Newton Pool. It produced in the first twenty-four hours and for several succeeding days 65 barrels of oil. The well flowed through the gas pipe and pumped through the tubing. When the well was a year old it was producing 13 barrels a day. It is now (December, 1904) producing 2 barrels a day.

Diameter, 5⅝ inches from 0 to 275 feet. Length of casing, 275 feet. Initial pressure, 85 pounds.

*266. Well No. 2 on the Philadelphia tract, Gilson Pool, 3 miles west of Grand Valley, Eldred Township, Warren County, Pa.*

[Completed February, 1891 Authority, Josiah G. Winger, contractor.]

| | Feet. |
|---|---|
| Subsoil; conductor hole 16 inches in diameter | 0– 18 |
| Hard sandy shale (limy) | 18–100 |
| Soft gray sandstone, water | 100–135 |

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| | Feet. |
|---|---|
| Soft black shale | 135–150 |
| Hard gray sandstone; first stratum of First sand | 150–160 |
| Soft black shale | 160–170 |
| Soft gray sandstone; second stratum of First sand; salt water cased off | 170–185 |
| Soft blue shale; end of 8-inch hole and end of 5⅝-inch casing | 185–200 |
| Soft black shale | 200–223 |
| Hard white sandstone, pebbly; Second sand. This 11 feet of sand overlies the oil stratum. It is separated from the lower stratum by a layer of shale 6 inches thick | 223–334 |
| Soft white sandstone, pebbly. This 21 feet of oil sand is very coarse, full of pebbles, and easy to drill. Oil, gas, and salt water in this lower stratum of the Second sand | 334–355 |
| Black shale; "gravel bed" from 661 to 671 feet | 355–375.5 |

This is the best Second sand pool in this oil field. The sand is very porous. One well of the pool has a record of over 6,000 barrels of oil in its first year. The best wells found in the pool are located on the Theodore Gilson farm, on the Spring Creek and Titusville public road. The pool was developed by Stewart Brothers and later by Tait & Patterson. Yield for the first twenty-four hours, 32 barrels of high-grade oil.

*278. Well No. 19, on the Sayers farm, three-fourths mile southeast of Grand Valley, Eldred Township, Warren County, Pa.*

[Begun November 14; completed November 22, 1904. Authority, Josiah G. Winger.]

| | Feet. |
|---|---|
| Soft brownish yellow clay | 0– 20 |
| Soft brownish yellow quicksand and blue clay | 20– 80 |
| Soft blue clay and gravel | 80–100 |
| Soft gray sandy clay and gravel | 100–120 |
| Hard blue sandstone | 120–140 |
| Soft variegated sandstone; 5 feet of First sand at 155 feet | 140–180 |
| Hard black shale | 180–300 |
| Hard gray sandy shale | 300–315 |
| Soft blue shale | 315–340 |
| Hard blue shale | 340–400 |
| Hard blue sandy shale | 400–420 |
| Hard gray shale and sandstone | 420–440 |
| Hard gray conglomerate; Third sand; oil in first 10 feet | 440–460 |
| Hard white sandstone; salt-water sand | 460–485 |
| Gray sandstone; gas sand | 485–490 |
| Soft white sandstone; oil sand, the lower stratum of Third sand | 490–500 |
| Hard shale | 500–520 |

The quantity of salt water is small, on account of the remarkably fine texture of the salt-water stratum. The sand in a well drilled for the Stanton Oil Company in 1890, only 80 feet distant from this one, was much coarser than this, and the salt water was so plentiful that the company abandoned the well.

Diameter of well, 8 inches from 0 to 310 feet, 8-inch drive pipe from 0 to 140 feet, 6½-inch casing from 140 to 310 feet. Before the 6½-inch casing was placed fresh water rose to within 60 feet of the mouth of the well. Yield of oil the first twenty-four hours, 12 barrels.

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*279. Well No. 4 on the Smith farm, 2½ miles east of Grand Valley, Eldred Township, Warren County, Pa.*

[Begun October 11; completed October 29, 1904. Authority, Josiah G. Winger, contractor.]

| | Feet. |
|---|---|
| Soft yellow subsoil | 0– 17 |
| Soft gray shale | 17– 60 |
| Gray sandy shale; Mountain sand | 60–100 |
| Hard gray sandstone; water sand between 160 and 220 feet | 100–220 |
| Soft gray shale | 220–235 |
| Hard gray and black sandy shale | 235–315 |
| Hard gray, fine-grained sandstone; the "Cap" | 315–335 |
| Gray sandstone; oil and gas in small quantities | 335–355 |
| Light gray sandstone and shale | 355–376 |
| Soft gray and white conglomerate | 376–387 |
| Gray sandy shale | 387–420 |
| Gray shale | 420–460 |
| Soft black shale | 460–520 |
| Gray fine sandstone; top of Third sand at 570, but irregular, here represented by a mixture of shale and dark-colored sandstone | 520–590 |
| Soft gray sandstone; "Gas sand," inferior quality, no gas found | 590–598 |
| Soft light-gray sandstone | 598–605 |
| Soft white sandstone; oil sand. One gallon of oil was washed from the sediment from this 5 feet of drillings | 605–610 |
| Soft black shale | 610–632 |

The well stood thirty-six hours before it was torpedoed, and had accumulated 5 gallons of oil. Forty-five minutes after torpedo was exploded oil rose in the well to a height of 130 feet. The well produced 12 barrels of good oil the first twenty-four hours.

In this pool the last stratum of the Third sand is pay, and is designated "Newton sand." Farther south the first stratum is oil bearing, and is designated "Grand Valley sand." In a few wells, from 3 to 6 miles south, pay is found in both the upper and lower strata of the Third sand.

Diameter of well, 8 inches from 0 to 235 feet, 5⅝ inches from 235 to 632½ feet. Length of casing, 235 feet.

*284. Well No. 25 on the Sturges farm, 4 miles south of Grand Valley, southwest township, Warren County, Pa.*

[Begun October 3; completed October 14, 1904. Authority, P. B. McCool, driller.]

| | Feet. |
|---|---|
| Soil; shell at 32 feet | 0– 40 |
| Soft shale; soft water at 55 feet; shell 60–80 (sandstone 100–120) | 40–240 |
| Hard gray sandstone; Mountain sand | 240–280 |
| Gray shale and shells | 280–440 |
| Gray sand shells; first oil at 460 | 440–500 |
| Gray sandstone; First sand | 500–545 |
| Soft gray shale, shelly from 620 to 690 | 545–690 |
| Gray sand shells; Second sand | 690–753 |
| Hard gray sandstone; Third sand | 753–774 |
| Soft gray shale | 774–789 |

Diameter of well, 8¼ inches from 0 to 285 feet; 5⅝ inches from 285 to 789 feet; length of casing, 285 feet; amount of oil obtained, 5 barrels a day.

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*285. Well No. 7 on the Speer heirs farm, 1½ miles north of Thomas, Washington County, Pa.*

[Begun October 20; completed December 20, 1904. Authority, James Lyle, contractor.]

| | Feet. |
|---|---|
| Soil | 0– 20 |
| Hard gray limestone | 100– 150 |
| Hard gray limestone, shaly | 150– 200 |
| Soft dark-gray shale | 200– 250 |
| Soft light-gray shale | 250– 330 |
| Pittsburg coal | 330– 336 |
| Hard gray limestone | 336– 380 |
| Hard gray shale | 380– 450 |
| Soft red shale | 450– 500 |
| Soft gray shale | 500– 550 |
| Soft red shale | 550– 600 |
| Soft greenish shale | 600– 750 |
| Hard gray sandy shale with some lime | 750– 800 |
| Soft blue sandy limestone | 800– 850 |
| Hard light-gray sandstone | 850– 900 |
| Soft light-gray sandstone | 900– 950 |
| Soft dark-gray shale | 950–1,000 |
| Dark-gray shale, sandy | 1,000–1,082 |
| Coal; fresh water | 1,082–1,087 |
| Soft light-gray sandy shale | 1,087–1,200 |
| Soft light-gray sandstone | 1,200–1,250 |
| Soft white sandstone; gas at 1,285 feet | 1,250–1,325 |
| Soft dark-gray shale | 1,325–1,400 |
| Hard gray sandstone | 1,400–1,500 |
| Hard light-gray sandstone | 1,500–1,710 |
| Soft gray shale | 1,710–1,930 |
| Hard gray shale | 1,930–1,990 |
| Hard gray shaly sandstone | 1,990–2,050 |
| Light-gray sandstone | 2,050–2,100 |
| Soft light-gray sandy shale | 2,100–2,180 |
| Soft light-gray sandstone | 2,180–2,243 |
| Blue shale and white sandstone | 2,243–2,246 |
| Hard gray sandstone; oil sand; steel-line measurement | 2,246–2,252 |
| Soft gray sandstone; pay, oil and a little water | 2,252–2,255 |
| Hard white sandstone | 2,255–2,275 |

Diameter of well, 13 inches from 0 to 340 feet, 10 inches from 340 to 696 feet, 8 inches from 696 to 1,547 feet, 6⅝ inches from 1,547 to 2,275 feet. Yield, 15 barrels a day.

*301. Well 1¼ miles west of Houston, Harris County, Tex.*

[Begun December, 1903; completed February, 1904. Authority, J. Crummy, civil engineer, Houston Water Company.]

| | Feet. |
|---|---|
| Reddish sand | 0– 30 |
| Soft gray clay | 30– 44 |
| Soft red sand and rock | 44– 74 |
| Hard red clay | 74– 89 |
| Sand and gravel | 89– 93 |
| Hard white clay | 93–137 |
| Red sand | 137–210 |



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| | Feet. |
|---|---|
| Red clay and gravel; hard drilling | 210– 290 |
| Whitish sand and gravel; hard drilling | 290– 316 |
| Reddish clay and gravel; hard drilling | 316– 356 |
| Red sand; hard drilling | 356– 393 |
| White clay and gravel | 393– 456 |
| Light-gray sand | 456– 496 |
| Clay and gravel | 496– 514 |
| Light-gray sand | 514– 526 |
| Gravel | 526– 532 |
| Whitish clay | 532– 570 |
| Very hard rock | 570– 571 |
| White sand and gravel | 571– 585 |
| Reddish clay | 585– 600 |
| Porous rock | 600– 602 |
| White clay | 602– 608 |
| Sand and gravel | 608– 618 |
| Clay | 618– 658 |
| White gravel and clay | 658– 668 |
| Sand | 668– 678 |
| Porous whitish clay and rock | 678– 687 |
| White sand | 687– 705 |
| Clay and gravel; hard drilling | 705– 745 |
| Whitish sand | 745– 756 |
| White clay | 756– 772 |
| Sand | 772– 810 |
| Clay | 810– 815 |
| Sand | 815– 835 |
| White clay | 835– 895 |
| White sand | 895– 940 |
| Reddish clay | 940–1,134 |
| Hard rock | 1,134–1,137 |
| Light-gray sand | 1,137–1,179 |
| Clay | 1,179–1,236 |
| Whitish sand | 1,236–1,314 |
| Hard rock | 1,314–1,315 |
| Clay | 1,315–1,354 |
| Sand | 1,354–1,368 |
| Clay | 1,368–1,430 |
| White sand and gravel | 1,430–1,470 |
| Hard clay and rock | 1,470–1,600 |
| Hard rock; gas | 1,600–1,605 |
| Clay | 1,605–1,895 |
| Sand | 1,895–1,907 |
| Red clay | 1,907–2,025 |

Diameter of well, 8 inches from 0 to 779 feet, 6 inches from 479 to 1,219 feet, and 4 inches from 1,219 to 1,225 feet.

The Houston Water Company has 3 wells in stratum between 137 and 200 feet, 6 between 290 and 316, 5 between 456 and 496, 2 between 571 and 585, 1 between 602 and 618, 5 between 687 and 705, 6 between 772 and 810, 4 between 895 and 940, 4 between 1,137 and 1,139, and 3 between 1,236 and 1,314 feet. All the wells are located within half a mile radius. They have a closed pressure at the surface of from 1 to 18 pounds and flow from 1,000 to 8,000 gallons a day each.

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*302. Well No. 1 on the L. W. Long farm, Humble (17 miles north of Houston), Harris County, Tex.*

[Begun September 17, completed December 22, 1904. Authority, P. M. Cranberry, owner.]

| | Feet. |
|---|---|
| Soft gray sand | 30– 40 |
| Hard gray clay | 40– 60 |
| Hard bluish sand | 60–215 |
| Hard gray sand and clay | 215–310 |
| Hard blue sand and clay | 310–400 |
| Coarse gray sand | 400–470 |
| Fine gray sand | 470–495 |
| Hard blue clay | 495–508 |
| Hard blue sand and clay mixed | 508–572 |
| Hard blue clay | 572–645 |
| Hard blue sand and clay in alternate layers | 645–710 |
| Hard blue shale | 710–950 |
| Mixed rock and sand (limy) | 950–990 |

Marsh gas between 215 and 508 feet. Considerable gas between 645 and 670 feet and a little between 670 and 790 feet. Some oil and much gas between 790 and 950 feet. Oil between 951 and 990 feet. Yield, 100 barrels first twenty-four hours; gravity, 28° Baum.

Diameter of well, 11⅝ inches from 0 to 310 feet, 6 inches from 310 to 950 feet. Strainer inserted at 951 feet.

*318. Well No. 1 on the O. Simmons farm, three-fourths mile southwest of forks of Little Sandy, Elk Township, Kanawha County, W. Va.*

[Begun September 24, completed November 24, 1904. Authority, J. G. Weller, driller.]

| | Feet. |
|---|---|
| Surface soil | 0– 22 |
| Sand (sandy clay or shale) | 22– 40 |
| Shale | 40– 60 |
| Sandstone; fresh water rose to within 20 feet of surface | 60– 70 |
| Soft red shale | 70– 76 |
| Soft gray sandstone | 76–124 |
| Hard white shale (greenish) | 124–155 |
| Light-gray sandstone; fresh water rose to within 10 feet of the surface | 155–170 |
| Hard light-gray shale | 170–178 |
| Hard light-gray limestone (sandstone) | 178–184 |
| Hard light-gray sandstone | 184–227 |
| Hard gray shale | 227–233 |
| Hard light-gray sandstone | 233–300 |
| Hard light-gray shale | 300–306 |
| Hard white sandstone | 306–318 |
| Black shale, shelly | 318–410 |
| Coal | 410–412 |
| Black shale, shelly; water cased off at 425 feet | 412–452 |
| Hard white sandstone | 452–547 |
| Black shale, shelly | 547–685 |
| Hard white sandstone | 685–730 |
| Black shale, shelly | 730–740 |
| Hard white sandstone | 740–790 |
| Black shale, shelly | 790–857 |

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| | Feet. |
|---|---|
| Hard white sandstone; top of Salt Sand; gas between 928 and 935; estimated yield 500,000 feet in twenty-four hours | 857– 935 |
| Soft white sandstone; salt water; steel line measurement | 935– 942 |
| Soft white sandstone; hole filled with flowing water | 942– 965 |
| Hard white sandstone | 965– 990 |
| Hard white sandstone (brown); well stopped flowing | 990–1,010 |
| Hard gray and brown sandstone | 1,010–1,143 |
| Hard black shale | 1,143–1,145 |
| Hard white sandstone | 1,145–1,195 |
| Hard dark-gray limestone; Bastard | 1,195–1,210 |
| Hard white sandstone | 1,210–1,329 |
| Soft white shale (blue) | 1,329–1,345 |
| Hard white sandstone; Maxton and Cairo oil sand | 1,345–1,365 |
| Hard white sandstone; bottom of Salt sand | 1,365–1,402 |
| Black shale, shelly; pencil slate | 1,402–1,405 |
| Hard gray limestone, "Big lime" | 1,405–1,510 |
| Hard gray limestone; should be Keener sand, was hard and limy | 1,510–1,554 |
| Soft gray sandstone, "Big Injun sand" | 1,554–1,615 |
| Black shale, shelly | 1,615–1,700 |

The gas in the Salt sand was drowned out by salt water at 1,010 feet. Well dry, casing pulled.

There was no distinction between Keener and Big Injun sands as there should be. Shale brake between Keener and Big Injun sand.

Diameter of casing 10 inches from 0 to 40 feet, 8 inches from 40 to 425 feet, 6⅝ inches from 425 to 1,345 feet.

*320. F. D. Hawkins No. 1, Harrisville, Ritchie County, W. Va.*

[Authority, W. F. Graham.]

| | Feet. |
|---|---|
| Limestone | 190–202 |
| Coal and shale | 202–208 |
| Limestone and pyrite | 208–220 |
| Gritty limestone | 220–250 |
| Red limestone (brown shale) | 258–266 |
| Gray limestone | 266–274 |
| Gray shale | 274–290 |
| Shale, coal and pyrite | 290–298 |
| Gray sandstone | 298–306 |
| Limestone (sandstone) | 306–314 |
| Gray shale | 314–322 |
| Limestone (limestone and shale) | 322–351 |
| Gray sandstone | 351–358 |
| Limestone (sandstone) | 358–365 |
| Sandstone | 365–384 |
| Red rock, "Little Red" | 384–408 |
| Limestone (shale) | 408–422 |
| Shale | 422–446 |
| Gritty limestone (gray sandstone, limy) | 446–467 |
| Shale | 467–482 |
| Limestone (shale) | 482–489 |
| Shale | 489–497 |
| Limestone (sandstone and shale) | 497–608 |
| Red rock, "Big Red" | 608–664 |

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| | Feet. |
|---|---|
| Sandstone; pyrite | 664– 670 |
| Limestone (gray sandy shale, limy) | 670– 781 |
| Shale | 781– 805 |
| Limestone; pyrite between 813 and 821 (shale between 821 and 852) | 805– 852 |
| Shale | 852– 867 |
| Limestone (shale) | 867– 873 |
| Shale and pyrite | 873– 879 |
| Limestone (shale) | 879– 885 |
| Shale | 885– 892 |
| Limestone (shale) | 892– 916 |
| Shale | 916– 930 |
| Limestone (shale) | 930– 986 |
| Sandstone (red shale) | 986– 992 |
| Shale | 992–1,006 |
| Limestone (shale) | 1,006–1,018 |
| Shale | 1,018–1,032 |
| Limestone (shale) | 1,032–1,045 |
| Sandstone; Dunkard Sand | 1,045–1,155 |
| Shale (coal at 1,219) | 1,155–1,219 |
| Sandstone | 1,219–1,225 |
| Shale | 1,225–1,241 |
| Sandstone; Second Cow Run sand | 1,241–1,285 |
| Coal | 1,285–1,300 |
| Sandstone | 1,300–1,312 |
| Shale | 1,312–1,328 |
| Sandstone | 1,328–1,340 |
| Shale | 1,340–1,348 |
| Limestone (shale) | 1,348–1,354 |
| Shale | 1,354–1,378 |
| Limestone (shale) | 1,378–1,385 |
| Shale; shells from 1,408 to 1,414 feet | 1,385–1,438 |
| Sandstone; Gas sand | 1,438–1,463 |
| Shale | 1,463–1,575 |
| Sandstone; Salt sand | 1,575–1,614 |
| Shale | 1,614–1,662 |
| Shells; Maxton | 1,662–1,669 |
| Limestone | 1,669–1,696 |
| Shale; Cairo | 1,696–1,699 |
| Limestone, "Big lime;" top of Keener at 1,752 feet, very small showing of gas. Very small showing of light yellow oil between 1,782 and 1,788 feet. Steel line measurements at 1,762 and 1,770 feet | 1,699–1,807 |
| Sandstone and shale; brake | 1,807–1,813 |
| Sandstone, "Big Injun;" pay, gas and oil, 1,856–1,862 feet. Steel line measurement taken at 1,868 feet | 1,813–1,873 |
| Shale | 1,873–1,875 |

Shot with 10 quarts of glycerine and produced 12 barrels flowing.

Dr. George H. Ashley made the following report to Mr. W. F. Graham regarding the geological formations encountered in this well:

"The well appears to have started at about the horizon of the Washington coal. The coal noted at 298 feet is about at the horizon of the Uniontown. The sandstone at 467 feet may be the Sewickley sandstone. The horizon of the Pittsburg coal probably comes at a depth of between 500 and 550 feet. The sandstone between 1,045 and 1,155 feet is probably the Mahoning or 'Cow Run' sandstone.

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The coal at 1,219 may be the Lower Freeport or one of the Kittanning coals. The coal at 1,300 may be the Lower Kittanning or Clarion coal. Sandstone and shale from 1,438 to 1,496 is probably Pottsville, including the Salt sand at the horizon assigned by Mr. Graham. The lower part of the section has probably been correctly referred by Mr. Graham, unless it be in the case of the Keener sand, which he has correlated with the Siliceous limestone at 1,752 feet. The existence of a considerable thickness of limestone below would indicate that this occurs in the Big Lime (Greenbrier limestone), and that the Keener occurs in the upper part of the Big Injun immediately below 1,807 feet."

*323. Well No. 1 on the J. Murphy farm, 2 miles east of Hundred, Wetzel County, W. Va.*

[Begun July 25, completed September 24, 1904. Authority, E. J. Akins, driller.]

| | Feet. | |
|---|---|---|
| Alluvium | 0– | 13 |
| Hard limestone | 13– | 40 |
| Soft shale | 40– | 60 |
| Limestone and shale; 200 barrels a day of fresh water, slightly sulphurous, caseoff at 115 feet. | 60– | 352 |
| Coal | 352– | 355 |
| Shale and soft limestone | 355– | 425 |
| Coarse white sandstone | 425– | 445 |
| Soft black shale | 445– | 480 |
| Coarse white sandstone | 480– | 500 |
| Fairview or Waynesburg coal | 500– | 505 |
| Coarse white sandstone. These layers of sandstone are soft but wear the bit out of gage | 505– | 580 |
| Hard limestone; does not wear the bits | 580– | 640 |
| Harder limestone; breaks heads of bits | 640– | 740 |
| Coal; Mapletown | 740– | 745 |
| Hard limestone | 745– | 750 |
| Shale | 750– | 790 |
| Hard limestone | 790– | 825 |
| Soft chalky limestone | 825– | 844 |
| Coal; Pittsburg | 844– | 852 |
| Limestone and shale | 852– | 870 |
| Gritty limestone | 870– | 890 |
| Lime shells and shale | 890– | 960 |
| Soft pink rock | 960– | 980 |
| Red and white cave rock | 980–1, | 234 |
| Sandstone; Little Dunkard sand | 1,234–1, | 275 |
| Soft shale | 1,275–1, | 312 |
| Sandstone; Big Dunkard sand | 1,312–1, | 348 |
| Shoft shale | 1,348–1, | 400 |
| Sandstone; Lower Dunkard sand | 1,400–1, | 475 |
| Coal (black shale) | 1,475–1, | 480 |
| Sandstone; "Gas" sand | 1,480–1, | 610 |
| Shale | 1,610–1, | 650 |
| Sandstone; Salt sand, dry in this well | 1,650–1, | 890 |
| Shale | 1,890–1, | 980 |
| Sandstone; Maxton sand, generally called "Little lime." This sand produces paying oil wells of 100 barrels a day within 1 mile of this well. This well yields about 250,000 feet of gas a day from the pay between 1,995 and 2,005 feet | 1,980–2, | 030 |
| Shale and lime shells | 2,030–2, | 044 |

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| | Feet. |
|---|---|
| Limestone; Big lime | 2,044–2,145 |
| Sandstone; Big Injun sand; some gas between 2,145 and 2,155 feet. The well will yield about 200,000 feet a day from this pay | 2,145–2,343 |
| Shale with limestone and sand shells | 2,343–2,900 |
| Sandstone; Fifty-foot sand | 2,900–2,970 |
| Shale | 2,970–2,988 |
| Sandstone; Gordon Stray sand | 2,988–3,008 |
| Shale; brake | 3,008–3,009 |
| Sandstone; Gordon sand; a little gas, about 50,000 feet a day, between 3,000 and 3,020 feet | 3,009–3,040 |
| Shale | 3,040–3,055 |
| Sandstone; Fourth sand; this is the sand the well was drilled for. A well flowed 50 barrels an hour 1,000 feet from this well. This one, however, is dry | 3,055–3,075 |
| Shale and shells | 3,075–3,100 |
| Shale | 3,100–3,236.5 |

The Fourth sand formation and also the Bayard Sand were missing in this well.

Diameter of casing 10 inches from 0 to 115 feet, 8 inches from 115 to 1,234 feet, 6 inches from 1,234 to 2,132 feet.

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# PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

[Bulletin No. 264.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of the United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

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Correspondence should be addressed to

THE DIRECTOR,
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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

# GEOLOGY OF THE BOULDER DISTRICT, COLORADO

BY

N. M. FENNEMAN



WASHINGTON
GOVERNMENT PRINTING OFFICE
1905

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# LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
*Washington, D. C., November 18, 1904.*

SIR: I transmit herewith the manuscript of a report on the geology of the Boulder district, Colorado, by N. M. Fenneman, and recommend its publication as a bulletin. The report has grown out of a study of the Boulder oil field, begun by Doctor Fenneman in 1902, when this field first came into prominence. Two preliminary reports, giving the more important facts of economic interest bearing on the oil field, together with records of drilling and production, have been published in Bulletins 213 and 225, Contributions to Economic Geology, 1902 and 1903. The present report covers the general geology of the district, its physiography, stratigraphy, and structure, as well as its economic mineral resources, including water, stone, clay, coal, oil, and gas. It is a model discussion of a small but exceptionally interesting district, and will prove of both economic and scientific value.

Very respectfully,

C. W. HAYES,
*Geologist in Charge of Geology.*

Hon. CHARLES D. WALCOTT,
*Director United States Geological Survey.*



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# GEOLOGY OF THE BOULDER DISTRICT, COLORADO.

By N. M. Fenneman.

## INTRODUCTION.

The area described in this report is a rectangle 16 miles north and south by 9 miles east and west. The city of Boulder is situated southwest of its center. The immediate occasion of the survey was the finding of petroleum, supposedly in paying quantities. The chief exploitation for oil has been near the center of the area, from 2 to 4 miles northeast of Boulder.

The study was extended southward beyond the village of Marshall, where the structure is more apparent than it is farther north. The northern limit of the area mapped was determined largely by the broad elevation known as "Table Mesa," whose mantle of gravel conceals all the older strata for several miles, and which has not been pierced by the drill. It was found necessary to extend the work to the north side of this mesa, where there are exposures that furnish essential data for the structural problems. The work was carried east far enough to include the excellent exposures of the "White Rocks" at the south end of Gunbarrel Hill; it was extended west beyond the stratified-rock foothills, which contain the chief evidences of the structure.

It was necessary to make a careful study of areas at considerable distances from the oil wells, because the wells are located in the broad central portion of the district on the outcrop of the Pierre shales, which are in general so nonresistant and homogeneous that exposures of solid rock are extremely rare. Here and there in the fields, or on the side of an irrigating ditch, the presence of a thin harder bed may be indicated by a few rock fragments and a sandier soil, but generally the bed is not strong enough to cause even a small ridge, although a little excavation may sometimes reveal its position. Such indications and the inferences from the comparison of not very satisfactory well records are the only direct means by which the structure in the immediate vicinity of the oil wells can be determined.

It is otherwise on the borders of the area. On the west are fine exposures of the firm rocks of the foothills. On the south, in the



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Marshall coal field, are the eroded folds and scarps of the Laramie sandstone. On the east the Fox Hills and Laramie sandstones offer good exposures. At the north end Haystack Mountain, the only remnant of a terrace higher than Table Mesa, affords an excellent opportunity to study the Pierre shales. At this end of the field even the Pierre contains one or more sandstone strata, which outcrop in definite ridges. The structure of these surrounding districts affords a good basis from which to infer the probable deformations of the strata in the oil territory. It is evident that the structural features so clearly revealed in the foothill belt correspond to those of the oil field. Although the structural features of the shales of the oil field can be made out only by wearisome search, their correlatives in the foothills are open to the light of day. The practical significance of this relation will be evident to any who may be prospecting for similar deposits of oil along the front of the range.

The district here described was studied by the Hayden Survey, and its general features are discussed in the reports of that organization published in 1869 and 1872. The portion of the district south of Fourmile Canyon is included in the Denver basin, which is discussed in Monograph XXVII of the United States Geological Survey by Emmons, Eldridge, and Cross. The southern limit of the area mapped by the Fortieth Parallel Survey is a few miles north of the district, but the description of the major features of the stratigraphy of the east slope of the Front Range as given in the report of that organization is applicable to this field.

## ACKNOWLEDGMENTS.

The preparation of the map accompanying this report was made possible by the excellent base map prepared by Mr. Hugh F. Wade of Boulder, a large part of the geological field work having been done before the publication of the survey atlas sheets. Mr. Wade had also made a geologic map of a part of the region, a generalized reproduction of which is given in this paper as fig. 2 (p. 37). His careful observations were useful at various places, and a few of these are given specific mention in footnotes. Judge Junius Henderson has systematically collected fossils from the district and his cooperation was found valuable. At the present stage of the study, however, it was not deemed advisable to attempt a systematic treatment of the fossils. Mr. William R. Rathvon, who has handled for the United Oil Company practically the entire product of the oil field, has generously furnished exact data regarding shipments, and has given much general information concerning the industrial phases of the subject. The plates used are from photographs by Prof. F. R. Brackett. Over half of them were taken expressly for this publication. Prof. B

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George, of the University of Colorado, has been consulted on various questions; at the request of the writer he has studied several points in the field, and his conclusions have been received with much confidence. He has read the entire manuscript and his suggestions have been most helpful. The manuscript was subsequently submitted to Mr. George H. Eldridge, a student of oil fields, and one of the authors of the monograph on the Denver basin, who is familiar with much of the area and many of the features here described. Mr. Eldridge's criticisms were found especially pertinent, and on his suggestion certain changes were made.

## PHYSIOGRAPHY.

The area may be divided into three north-south strips. A narrow margin on the west belongs to the rough and dissected granite plateau, commonly considered a part of the Front Range of the Rocky Mountains. East of this is the narrow foothill belt, in which a descent of more than 1,000 feet is made to the plains, which form the eastern two-thirds of the area.

### TOPOGRAPHY OF THE AREA OF CRYSTALLINE ROCKS.

In a broad sense the name Front Range includes all of the Archean strip west of the Great Plains and the foothill belt. If this part of the range is looked at in more detail, there is seen near the middle of the strip a definite north-south ridge, having its crest about 18 miles west of the upturned strata of the foothills. West of Boulder this ridge reaches an elevation of from 12,000 to 14,000 feet, and has an average slope of from 500 to 1,000 feet in a mile. At approximately the 9,000-foot contour the slope changes. On the west is a relatively abrupt ridge, and on the east a much dissected plateau reaching to the foothills. (See Pl. III, *B*, opposite p. 12.)

The belt between the restricted mountain ridge on the west and the foothills on the east is 10 to 12 miles wide. Its generalized eastward slope is about 250 feet per mile, or from one-fourth to one-half that of the range proper. This strip is cut by narrow valleys to a depth of over 1,000 feet. The interstream areas are generally steep and narrow hills without flat tops, though some ridges continue for several miles with approximately level and unbroken crests. From any high point almost all the summits appear to be in the same plane. The range proper on the west and isolated lumps on the plateau rise with conspicuous abruptness, Sugarloaf Mountain, the top of which is 1,000 feet above the general level, being a prominent example. The topography at once suggests an imperfectly base-leveled surface that has been deeply cut by streams whose erosive power has been increased by recent elevation.

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## FOOTHILLS.

### MONOCLINAL RIDGES.

East of the granite are the red sandstones of the Fountain and Lyons formations, which have an average dip of more than 50° and form a ridge rising 1,000 feet above the plains. The sandstones have apparently resisted weathering better than the crystalline rock, as streams from the west which have cut only narrow canyons through the sandstone ridge generally receive tributaries that flow in north-south valleys in the granite just west of the contact. At places (as at South Boulder Peak) the ridge rises to several times its average height, and towers high above the plateau to the west.

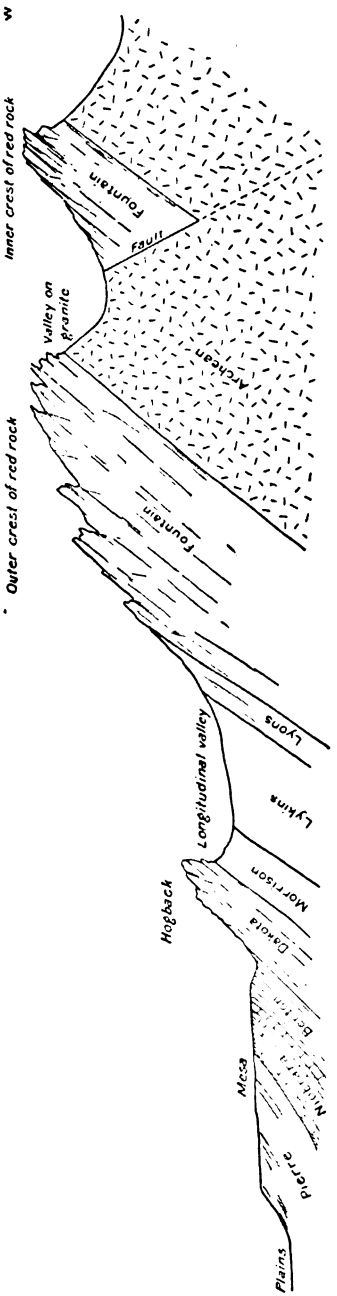
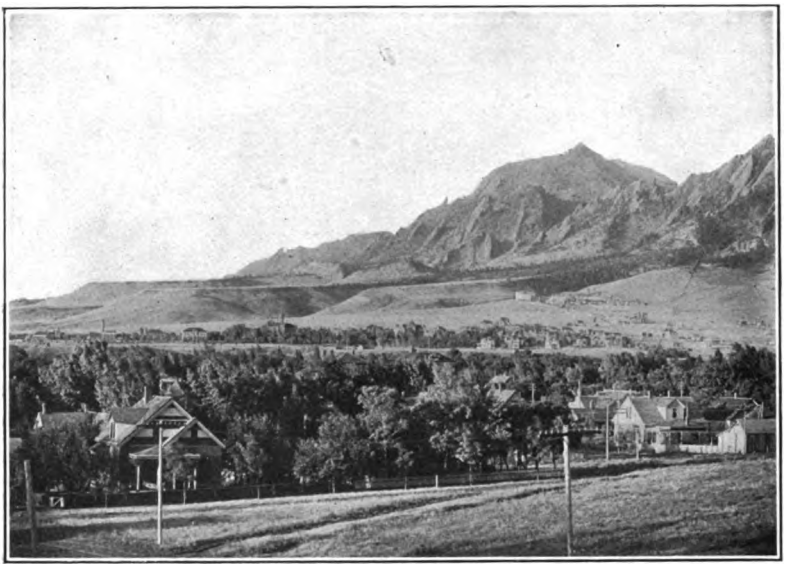



FIG. 1.—Generalized east-west cross section near Boulder. The diagram shows the structure of the South Boulder peaks, of Green Mountain, and of the ridge near Sixmile Canyon.

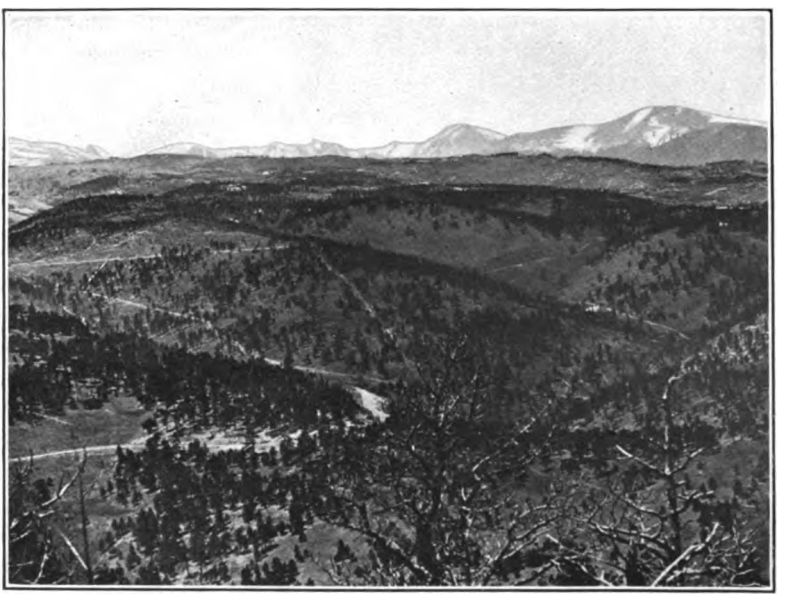
To these red sandstones, from 500 to 1,500 feet thick, is due a large part of the splendid scenery of this exceptionally fine stretch of foothills. At some places the ridge has an even crest and resembles a wall, while at other places its crags run upward in a long line of spires. (See Pl. III, A.) The bare red front of a single crag has sometimes an area of several acres. The outcrop here described may have one, two, or even three distinct crests. They are the westerly members of a series of monoclinal ridges known as "the foothills." Alternations of strong and weak strata, upturned at steep angles, offer the necessary conditions for the carving of these ridges and valleys.

The ridge-making outcrops, taken in order from west to east, are composed of the Fountain, the Dakota, and the Niobrara formations, the last named appearing as a prominent ridge only in the northern part of the area. The order of

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*A*. MESAS AND FOOTHILLS SOUTH OF BOULDER.



*B*. VIEW WESTWARD FROM GREEN MOUNTAIN.

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size is the same as that here given, the height decreasing from west to east.

The Dakota "hogback" is second in prominence to the Fountain crags. It is absent between Sunshine and Pole[a] canyons, but elsewhere it rises steeply to heights of from 100 to 500 feet. The light-gray color of its sandstones is frequently in strong contrast with the red of the rocks farther west. Its crest is commonly covered with pines.

### LONGITUDINAL VALLEYS.

Between the red-rock ridge and the Dakota the weaker rocks of the Lykins and Morrison have been cut out in a valley from one-fourth to one-half mile wide. (See fig. 1; also Pl. IV, *A*.) The brilliant color of the former, especially north of Boulder, has given an almost blood-red hue to the soils of the valley. A similar valley, though lacking the color, marks the outcrop of the Benton, where the Niobrara ridge is present. Where the latter forms no ridge, the Benton occupies a long slope from the Dakota hogback to the mesas. This slope is characteristically marked by landslides. At frequent intervals may be seen the typical hummocky topography due to this agency.

## MESAS.

East of the last foothill ridges the slope to the plains may be continuous or may be broken by a sharp step, leaving a high terrace adjacent to the foothills. This terrace is called a mesa, or locally "the mesa" (Pl. III, *A*). It occurs in fragments of unequal height abutting against the most easterly foothill ridge or separated from it by a trough due to recent erosion. (Compare Pl. V, *A*, p. 30.) These fragments are commonly separated from one another by ravines. These mesas have a height of from 100 to 300 feet above the lower plains, and a west-east width in this vicinity varying from a fraction of a mile to 3 miles.

### SLOPE AND HEIGHT.

The eastward slope of the terraces may be as great as 10° on the foothill side, but it diminishes rapidly toward the plains. At 1 mile east from the foothills a slope of 3° to 4° is common, and at 3 miles the slope is about 1°. An east-west cross section shows an even curve, like the profile of a stream. In addition to the east-

[a] This small gorge in the outer foothills, 2 miles south of Boulder Creek, is locally known as Skunk Canyon. It appears on the maps of the Denver basin as Pole Cat Canyon. For convenience the abbreviated form is here used. The small stream issuing from it is rarely spoken of by any name.

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ward slope there is generally a distinct northward or southward inclination toward a lower bench quite similar to the higher, but separated from it by a steep bluff, or more commonly by a ravine. In a general way the highest mesas are farthest from the larger streams, and the height diminishes as these streams are approached.

### STRUCTURE AND COVERING.

These mesas are essentially rock benches covered 10 or 20 feet deep with unassorted rock waste. The rocks, chiefly Pierre shales, are steeply upturned, being affected by the mountain uplift. They have been smoothly planed off, not to a flat but to an inclined surface. The débris covering may have a fairly uniform thickness of 20 feet on the highest benches. Generally speaking, the thickness is less in proportion as the mesa surface is lower. This thoroughly unassorted débris comprises fragments of all sizes from sand grains to bowlders more than 10 feet in diameter. The heaviest bowlders are close to the foothills, but fragments a foot or more in diameter are found some miles to the east. On the highest mesas these fragments are almost exclusively from the red rock. The lower benches contain varying proportions of crystalline rock mixed with the débris of red sandstone. The bowlders of the present flood plains are almost exclusively from the crystalline rocks.

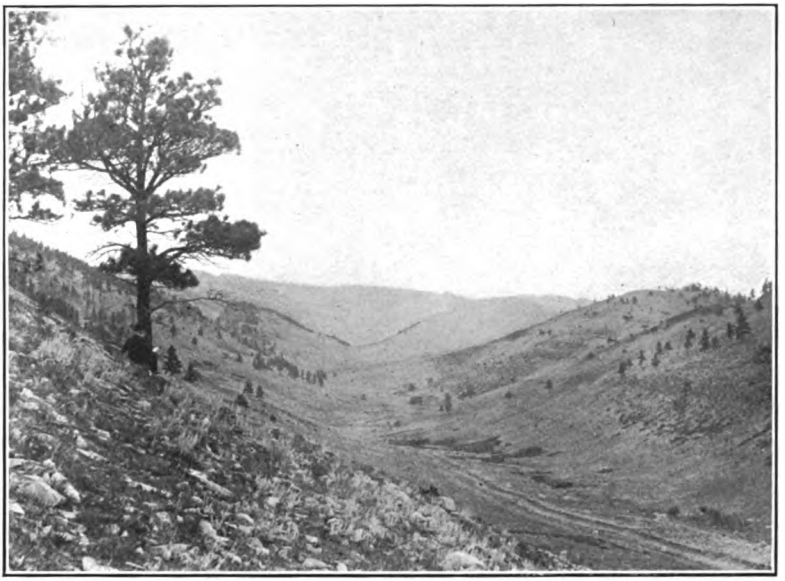
### ORIGIN.

Some similar mesas farther south have been described as river terraces; others have been ascribed to the cutting of lake shores.[a] It is believed that the mesas in the area here described are remnants of stream terraces,[b] and that the underlying rocks were planed off by the streams that deposited the unassorted débris, just as the present streams are eroding the shales and depositing unassorted material on the new surfaces—that is, on the present flood plains. This conclusion is based on the following facts: (1) The resemblance of the eastward slope of the mesas to the stream profile; (2) the northward or southward inclination of the mesa tops; (3) the variations in the heights of the mesas, the lower in general being nearer the larger streams; (4) the general resemblance of the escarpments to old river bluffs, the higher and lower mesas having the same relationship as higher and lower terraces, except that the mesa remnants are often widely separated by erosion. It is not to be

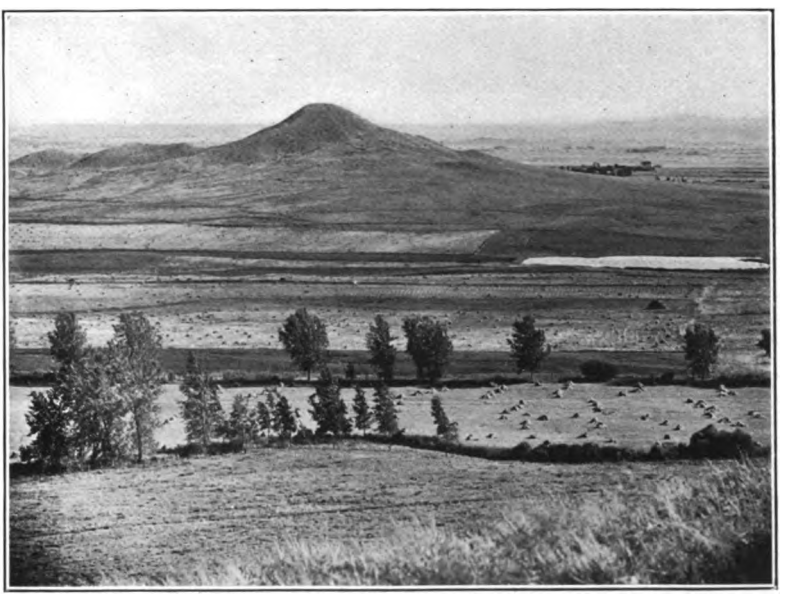
[a] Emmons, S. F., Geology of the Denver basin: Mon. U. S. Geol. Survey, vol. 27, 1896, p. 9.

[b] Compare Lee, W. T., The origin of the débris-covered mesas of Boulder, Colo.: Jour. Geol., vol. 8, p. 504.

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*A* LONGITUDINAL VALLEY IN THE FOOTHILLS NORTH OF BOULDER.



*B.* HAYSTACK MOUNTAIN.

View southward from Table Mesa.

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understood that all the mesas are the terraces of existing streams. The general decrease in height as the larger streams are approached might suggest such a relation, but this conclusion is not intended. In the discussion of drainage the location of several former streams concerned in mesa making is indicated.

The hypothesis that these mesas are stream terraces is strengthened by the objections to the hypothesis that they are lake terraces. On the latter assumption, there existed over the adjacent parts of the Great Plains a water body of large but unknown dimensions. The western shore of this lake lay, at first, a few miles east of the present foothill belt. The rocks of this shore were the upturned shales and soft sandstones of the higher Cretaceous series; the original offshore slope was relatively abrupt. Cliff cutting then caused the shore to recede to the present foothill belt. There was left a broad wave-cut terrace, of which the present mesas are remnants, and this marginal terrace was covered with the sheet of débris which now appears as the mesa covering. The facts not readily accounted for on this hypothesis are the following: (1) The absolutely unassorted nature and the frequent angularity of the débris; (2) the entire absence of the outer detrital or built portion of what must in all probability have been a cut-and-built terrace; (3) the difference in the height of terrace remnants abutting against the foothills; (4) the lateral (north or south) slope of the mesas; (5) the dominance of red-rock fragments on the higher mesas and of crystalline rock on the lower terraces, and (6) the lack of well-attested lacustrine deposits over the adjacent plains.[a]

In regard to (1) the fact that the débris is angular and is not assorted, it may be stated that detritus on marginal lake terraces is always assorted, while the thoroughly heterogeneous nature of the mesa gravels agrees to a nicety with that of the deposits of many overloaded streams in arid regions where the small streams are subject to quick alternations of flood and drought. With reference to (2) the absence of the built portion of a cut-and-built terrace, it may be noted that the mesas abut against the mountain front in a kind of embayment, and that a wave-cut terrace in such a situation might be expected to show a lakeward extension of detrital material. The absence of such materials is not believed to be adequately accounted for by subsequent erosion. In fact, a mesa composed entirely of such loose and porous materials as the present surface deposit would, in such a climate as this, be extremely unfavorable to the development of surface streams on account of the ready percola-

[a] Compare Johnson, W. D., The High Plains and their utilization: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1901, p. 653.

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tion of surface waters, and would therefore endure longer than a terrace of shales thinly covered by gravels. The significance of (5) the dominance of red-rock fragments on the higher mesas and of crystalline rock on the lower terraces is probably due to the fact that the streams were cutting through red rock when they were at the level of the highest mesas, but as they eroded deeper channels and flowed at lower levels they cut into and carried crystalline rocks. This is further discussed under the heading "Former westward extension of strata." The other objections enumerated above require no discussion.

Wherever the Hygiene sandstone is found it has been planed down to the level of the higher terraces. Upon their surfaces it does not appear, its edge being covered by the mesa gravels. North of Four-mile Canyon, however, wherever the higher terraces have been eroded away the Hygiene sandstone forms a bold ridge whose even crest has the same height as one of the widest terraces. When the sandstone was planed off to its present height this terrace was continuous across the present lowlands.

### FORMER WESTWARD EXTENSION OF STRATA.

Whatever streams may have built up any terrace, it is manifest that the oldest mesas are the highest and that the age decreases with diminishing height. Furthermore, the proportion of fragments of red rock to those of crystalline rock decreases as the terraces become lower or as the present flood plains are approached. From these facts it is fair to infer that when the streams were running at the level of the highest mesas they were cutting through red rock for some distance west of the present foothill belt. As a result of the headward elongation of the valleys and of down cutting through the stratified rocks to the granite, the streams carried increasing proportions of crystalline rock, until at present the red rock forms a very small part of the load and hence of the flood-plain débris. As there are no outliers of the red rock on the crystalline area to the west, it is impossible to make any but the roughest estimate of the width of the belt from which the stratified rocks have been denuded.

## DRAINAGE.

The district is drained by eastward-flowing streams, which are consequent upon the tilted surface, and is crossed by the two largest creeks—Lefthand and Boulder. South Boulder Creek, of about the same size, unites with Boulder Creek within the area. Most of the

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intermediate smaller streams coming from the foothills join these larger creeks within the area mapped.

### ADJUSTMENT TO STRUCTURE.

In the almost uniformly strong crystalline rocks to the west all the streams are cutting gorges. There is no progressive adjustment except that which comes from the more rapid widening of the larger valleys at the expense of the smaller. In the almost uniformly weak rocks of the plains all the streams have flood plains, though meandering is but little developed. Here also progressive adjustment to structure is not prominent.

Within the foothill belt the streams from the mountains cross alternately strong and weak strata. Here tributaries are developed in the longitudinal valleys, and at some places adjustment has resulted in stream capture. Across the outcrop of the Dakota and the Fountain the streams flow in steep gorges and corrade their channels with difficulty, while their tributaries in the longitudinal valleys erode the softer strata with ease. As a result, stream capture has taken place, and in the Fountain and Dakota ridges the abandoned channels now appear as small notches analogous to the wind gaps of the Appalachians.

### EXAMPLES OF STREAM CAPTURE.

In the Dakota hogback a notch representing a former stream channel appears just north of Bear Canyon. The stream flowing south of east from Green Mountain, and now tributary to the stream in Pole Canyon, lies in a direct line with this notch, and doubtless once crossed the Dakota at this place. At the same time a stream one-third of a mile farther north crossed the Dakota where the ridge was not only much lower and narrower, but was broken by the Pole Canyon transverse fault. In this gap the northern stream lowered its channel rapidly and a vigorous tributary from the south developed on the weak beds west of the Dakota ridge. The development of this tributary gorge was further favored by the eastward slipping of the Dakota ledges. (See p. 48.) The tributary gorge elongated headward until it captured the headwaters of the southern stream and caused its lower course to be abandoned. After this capture and sudden acquisition of more water the valley west of the Dakota ridge was rapidly cut down, and as the support of the steep slope on the west side of the hogback was removed landslipping occurred. (See p. 51.) A similar notch cuts the Dakota



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hogback 2 miles farther south and a large one occurs north of Fourmile Gulch. West of the place where Twomile Gulch breaks through the Dakota the ridge of red rock is indented by a notch whose history is similar to that of the notch near Bear Canyon.

The largest stream affected by capture is Lefthand Creek, which approaches the foothills from the west in sec. 26, 6 miles north of Boulder. When this creek reaches the middle of the belt of red rock it turns at right angles and flows north for 1½ miles; it again turns east at Altona, crosses the remaining foothill outcrops, and emerges upon the plains. Almost directly east of its last bend to the north is a sag of more than 100 feet in the Dakota ridge to the east. The drainage channel leading east from this sag, though occupied by a very small stream, pursues an independent course for many miles. It is locally known as Dry Creek, a name applied also to another small stream 5 miles farther south. Along the northern Dry Creek are evidences of a former larger stream—the lower course of Lefthand Creek—which once crossed the foothills in a direct easterly course. Another stream (the present Lefthand Creek) that crossed the foothills at Altona had a course more favorable to down cutting and was able to develop a tributary on its south side, whose headwaters worked far enough south to tap the former Lefthand Creek. The old valley for a short distance east of the "elbow of capture" is now occupied by a small westward-flowing stream which joins Lefthand Creek where it turns to the north.

This recent shifting of the position of Lefthand Creek explains the otherwise anomalous circumstance that Haystack Mountain (Pl. IV, *B*), the highest mesa remnant in the region, lies close to one of the largest streams, which, as already pointed out (p. 14), are near the lowest mesas. The anomalous position of Haystack Mountain is due to the fact that previous to the capture described this mesa was well removed from lines of active erosion.

The terraces to the east offer further interesting evidence concerning the former character of the streams. These terraces are planation surfaces due to meandering and are not base-levels. Some of them are miles in width, indicating that the streams which made them must either have worked a very long time at the same level or have been of considerable size. Knowledge of either one of these conditions, therefore, sheds light upon the other.

As an illustration of the above, much of the surface between Table Mesa and the high mesa 4 miles north of Boulder Creek, a stretch of 3 miles, is at one level, about 150 feet below Table Mesa. The bottoms of the present valleys are from 50 to 75 feet below this lower terrace. Where this terrace has been eroded away by the present

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streams the strong Hygiene sandstone stands out as an even-topped ridge, rising to the exact height of this lower terrace. Where the lower terrace has not been eroded the Hygiene sandstone does not appear, having been planed off by meandering streams and covered with the coarse gravel that mantles the mesas and terraces. Small streams now cross the Hygiene sandstone in narrow gorges. All flood plains and low terraces of present streams are narrow in comparison with the broad surface of planation, which has the same height as the top of the sandstone ridge. If the present small streams planed off the broad surface 150 feet below that of Table Mesa, they must have worked longer at one level than would be consistent with the present rate of down cutting.

On the other hand, it is noteworthy that this broad planation surface lies along the course followed by Lefthand Creek before the stream had been shifted northward by the capture described above. This stream was approximately as large as Boulder Creek, and its planation surface is as broad as that of the latter. The supposition that the present small streams meandered at one level long enough to make such a broad planation surface would involve conditions of level or of climate which are not supported by the other evidence.

## NATURAL LAKE BASINS.

Scattered over the plains is a considerable number of ponds, some of which have an area of 100 or 200 acres. All of these are used for storage of irrigation waters, and have had their capacities materially enlarged by dams. Some are due entirely to the damming of valleys or "draws," but others are natural basins. Marshall Lake and Boulder (Weisenhorns) Lake are good examples of the latter type. These natural basins are not confined to the surficial sheet of rough gravel, but are often deep in the shales. They originated later than the mesas or terraces which surround them. Some of the small ones might have originated by small landslips or creep, resulting in the damming of small valleys, but most of them can not be thus explained. Boulder Lake has a nearly flat bottom at a depth of approximately 20 feet. The fraction of this depth due to damming, either natural or artificial, is insignificant.

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## STRATIGRAPHY.

The classification and nomenclature of formations used by Emmons and Eldridge for the Denver basin [a] is in the main followed in this paper. For the area here concerned the succession is as follows:

| | |
|---|---|
| Quaternary | Alluvium and terrace gravels. |
| Cretaceous | Laramie. |
| | Fox Hills. |
| | Pierre. |
| | Niobrara. |
| | Benton. |
| | Dakota. |
| Jurassic | Morrison. |
| Triassic (?) [b] | Lykins. |
| | Lyons. |
| | Fountain. |
| Algonkian | Quartzite of South Boulder Canyon. |
| Archean | Granites, etc. |

### ARCHEAN SYSTEM.

The sedimentary rocks of this district rest upon a basement of granite, granite-porphyry, and granite-gneiss, which are at some places gray, but more commonly range from flesh color to red. This basement is cut by frequent dikes; several prominent ones have a north-northwest direction, others trend south of east. These dikes are commonly composed of pegmatite, but there are also several of a light-greenish felsitic porphyry, similar to those which intrude the sedimentaries of the foothills.

The contact of this Archean foundation with the overlying sedimentaries is not a plane, but, in this district at least, the undula-

[a] Mon. U. S. Geol. Survey, vol. 27, 1896.

[b] The writer is indebted to Mr. George H. Eldridge, one of the authors of the monograph on the Denver basin, for the following note on the group heretofore called Wyoming and tentatively regarded as Triassic:

"Mr. N. H. Darton, of the United States Geological Survey, has had, since the publication of the Denver monograph, especial opportunity to study the sedimentary formations from the Black Hills in South Dakota to the southern portion of the frontal ranges of the Rocky Mountains in New Mexico, and is of the opinion, from evidence accumulated by him, that the "Red Beds" [Fountain] and their overlying "Creamy Sandstone" [Lyons], designated the Lower Wyoming in Monograph 27 of the United States Geological Survey, are Pennsylvanian in age, and that the series known as Upper Wyoming [Lykins] in that monograph is possibly Permian in the lower part and Triassic in the upper.

"The evidence leading to such an inference consists of the presence in the Red Beds, at one or more localities, of limestones containing Pennsylvanian fossils and of the presence of Permian fossils in the Black Hills in what he there correlates with the lower portion of the Upper Wyoming, in the Denver foothill region—that is, with the portion here consisting of the pink shales, fine sandstones, and curly limestones. The higher members of the Upper Wyoming may still be considered Triassic in the absence of evidence to the contrary."

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tions are very broad and gentle. The question whether this surface is due to subaerial or to marine deundation is discussed under the heading "Geologic history" (pp. 54–57).

## SEDIMENTARY ROCKS.

### ALGONKIAN SYSTEM.

#### QUARTZITE OF SOUTH BOULDER CANYON.

The oldest and lowest sedimentary rock is a quartzite which appears only at the extreme southern end of the area, in South Boulder Canyon. It is regarded as of pre-Cambrian age.[a] It is for the most part white, or stained pink with iron oxide; of medium texture, except at what seems to be the base, where it is a pebble conglomerate. One mile south of the southwest corner of the area mapped the beds are almost vertical and are cut across by the newly constructed grade of the Denver and Northwestern Railroad. The stratum is here 550 feet thick.

This formation does not rest upon the Archean surface at the same angle as the remaining strata. From a point at the base of the Fountain sandstone, which in general rests upon the granite, the quartzite strikes southwest, then for a space nearly west, and then S. 27° W. to far beyond the limits of the area mapped. It dips throughout to the southeast at angles ranging from 60° to 90°. Both north and south of it the same granite complex underlies the Fountain. In its relations to the higher stratified rocks the quartzite is only a part of the complex, on whose nearly plane surface the Fountain is laid down.

The structural relation of this single, steeply upturned stratum, outcropping in a narrow belt for many miles between inclosing granites, is not clear from observations made within this area. So small a part of its entire outcrop is included in this area that the attempt to decide its structural relations will not be made here. Marvine, in his description of the Front Range,[b] regards the granite as a mass of metamorphosed sedimentaries. According to this supposition, the quartzite is merely one of many metamorphosed strata, this one showing plainly its sandstone origin, while its neighbors have become entirely structureless. Van Hise, who has studied the contacts in South Boulder Canyon, believes that the phenomena of contact are those of a sedimentary formation laid down on a granite and gneiss floor.[c] He also thinks it probable that the

[a] Van Hise, C. R., Correlation papers, Archean and Algonkian: Bull. U. S. Geol. Survey No. 86, p. 325.

[b] Seventh Ann. Rept. U. S. Geol. and Geog. Surv. Terr., pp. 83–192.

[c] Van Hise, C. R., Manuscript notes to be used in a revision of pre-Cambrian rocks of North America (Bull. U. S. Geol. Survey No. 86).

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quartzite has been folded in, and that the structure is that of an isoclinal syncline.

### TRIASSIC (?) SYSTEM.

The rocks in this region, hitherto regarded as of Triassic age and called "Wyoming," embrace three formations—the Fountain, the Lyons, and the Lykins. The term "Red Beds" is popularly used without definite limitations; but the authors of the monograph on the Denver basin have conveniently limited the use of this term to the lowest and largest member of the series. The popular use of the term "red rock" is similarly restricted.

The subdivision into "Lower" and "Upper" Wyoming, adopted for the Denver basin, would also be appropriate to the Boulder area. The lower division, however, clearly embraces two lithological units which it is desired to distinguish in this report. The lower and major part consists chiefly of rather coarse, arkose sandstones and conglomerates of reddish color, while the upper and lesser part is a finer-grained, quartzose sandstone of white, "creamy," or light-reddish color. The coarse red sandstones were called the Fountain formation by Cross in the Pikes Peak folio, a type section being crossed by Fountain Creek, near Manitou. The summit of the Fountain formation is not exposed in the Pikes Peak quadrangle, but Darton[a] has found the character of the Fountain, as described by Cross, to continue to a white sandstone corresponding with the "creamy sandstone" of Eldridge, occurring in the Garden of the Gods, to which the name Lyons sandstone is here given.

#### FOUNTAIN SANDSTONE.

*Lithologic character.*—In general the Fountain sandstone is a rough arkose, the individual feldspars often appearing in large crystals. Locally it passes on the one hand into conglomerate and on the other into quartzose sandstone, excellent for building purposes, and even into shale. Micas are frequent, especially in the finer portions.[b] The conglomerate phase may have pebbles of granite and schist or of pure quartz only. The conglomerate of fragments of crystalline rocks is found only at the base, and there not universally. At places it is a beautiful recomposed granite, which at casual glance is not different from a coarse, reddish-brown original granite. Quartz-pebble conglomerate may be found at any or all horizons.

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[a] Bull. Geol. Soc. Am., vol. 15, p. 22.

[b] Prof. R. D. George, of the University of Colorado, has examined many specimens and finds that in large part, at least, this mica may be secondary and may have been derived from the feldspar.

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The cement of the mass is silica with an admixture of iron oxides; hence the quartzose beds weather with extreme slowness. Their fragments survive unchanged in the rubble of the mesas, where those of the crystalline rocks can be crushed in the hand.

The color of this rock in its coarser phases is due in part to its pink or red fragments of feldspar. In a large way this is more true of the lower horizons than of the upper, but the same factor is present in nearly all beds to a greater or less degree. In the cement, between the grains, crystals, and fragments, however, red iron oxide also appears, and in a general way affects the coloring in proportion to the fineness of the grain. Where quartz is more abundant the rock sometimes has a lighter color, which locally in loosely aggregated masses may even approach whiteness. Where this is the case it is composed almost entirely of large angular quartz grains that appear to have been assorted out of disintegrated granite, with almost no rounding by wear.

Occasional mottling in freakish forms is apparently caused by leaching of iron oxide by percolating waters. Where the differences in shade are attended by differences in texture, the darker colors occur in the denser portions where the water circulation has been least. In so far as the differential coloring is due to the action of percolating waters, doubtless a concentration of coloring matter in the denser portions has accompanied its leaching from the coarser.

*Structure.*—The Fountain sandstone is characterized by very thick beds throughout, and cross-bedding may be found at any horizon; at places there is a beautiful flow-and-plunge structure. It is very common to find pebble beds a few inches thick alternating with the finer sediments. Shale is found in distinct streaks or pockets. The thickness of these "Red Beds" is 500 to 600 feet at Boulder Canyon, where they are vertical, and increases both to the north and to the south, approximating 1,500 feet at Fourmile Canyon, where they dip eastward at an angle of 47°. No fossils have been found.

### LYONS SANDSTONE.

*Character and coloring.*—Above these massive beds and more or less arkose sandstones are other beds of purely quartzose sandstone. This upper formation is best developed at Lyons, a few miles north of the area mapped. It is quarried there in large amounts. The formation is named from that locality. The siliceous cement of this sandstone has sufficient iron to produce shades of pink, but the popular name, "creamy sandstones," conveys a wrong impression as to their color. While these beds have a fairly uniform shade they are locally almost white, and at some places red. Where these extremes occur, as at Fourmile Canyon, leaching and concentration of the coloring matter have often produced gaily colored rings and bands.

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An extreme phase of this feature is seen in the small red nodules which may even be found loose in their sockets in certain layers[a] and which may involve other causes in addition to those which make simple concretions. Many dendrite figures are found, some of marvelous beauty. They are sometimes obtained in thin flagstones, approximately 2 feet square, the entire side of such a slab being occupied by one symmetrical fern-like figure of exquisite delicacy. No fossils are found.

*Cross-bedding.*—The long washing and complete assortment which these sands underwent on the shore of the early sea was attended by cross-bedding of unusual dimensions and perfection. The angle of cross-bedding is occasionally as great as 35°. At nearly all of the many quarries opened in this stratum, flags or blocks are taken out along cross-bedding planes. This is not universally true outside the area represented by the map. At some of the Lyons quarries a part of the stone has been taken out along the true bedding, but this is not the rule.

The most striking feature of this cross-bedding, next to its universality and perfection, is its dip. With few exceptions this is at a lower angle than that of the true bedding. If, therefore, the strata were again horizontal the oblique lamination would dip toward the mountains; that is to say, toward the shore that existed at the time the beds were deposited. The significance of this is discussed under the heading "Geologic history."

This cross-bedded stratum reaches a maximum thickness of 297 feet at Fourmile Canyon, and is absent just south of Boulder Creek. It passes by gradations into the Fountain, or "Red Beds," below.

### LYKINS FORMATION.

*Character and thickness.*—Lying conformably upon the rocks just described, which are prevailingly sandstones and strong ridge makers, is a series of sandstones and sandy shales, with a little limestone. This series is the Lykins. The name is taken from Lykins Gulch, at the north end of the area mapped, the scenery along which owes its strange and beautiful character to this formation. It is clearly distinguished from the lower formations by its softness and by its showy colors, the most striking of which is a rich brick red that characterizes its sandy shales and shaly sands. At places the color is more brownish, but it is always deep and rich, and the long foothill valley, always present upon these soft rocks (fig. 1, p. 12; also Pl. IV, *A*, p. 14), is at places brilliantly colored.

The entire series is nowhere shown in a single section because it

[a] Eldridge (Monograph XXVII, p. 54) limits those at Golden to a horizon about 20 feet below the summit.

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is easily weathered and consequently thickly covered by waste. At Fourmile Canyon, where the formation is somewhat more than 800 feet thick, the lowest 230 feet are largely, if not wholly, sandstones of a clear red, a little darker than brick. These are overlain by the "crinkled" sandstone (see below), which is here 35 feet thick. Above this for 467 feet there are no exposures, but the soil is very red, and exposures not far distant indicate that most of this thickness is occupied by red arenaceous shales. Above these obscured beds are 100 feet more of the familiar red sandstone. Apparently any horizon of this formation may be slightly calcareous, but this is not general.

The section is essentially the same wherever seen, but the thickness varies greatly. The series is apparently absent just north of Gregory Canyon. If present at all it must have a thickness of only a few feet and is concealed beneath the sheet of waste which obscures almost all the strata between the Fountain and the Niobrara.

As indicated above, for a considerable portion of the column the nature of the rocks is for the most part concealed. At and beyond the north end of the area mapped there are certain slopes on which nearly the entire formation is exposed. Here it does not greatly exceed 300 feet, and, except for the "crinkled" sandstone, the whole exposure is of argillaceous sandstone, brick red in the main, but more brownish near the top. To this, however, must be added at the summit about 20 feet of light-pink or dull-yellowish, thin-bedded sandstone, slightly calcareous. This forms a kind of transition to the well-marked massive gray sandstone, which clearly belongs to the Jurassic.

Eldridge has described the Lykins under the name "Upper Wyoming" at localities farther south, where it contains "clayey strata of bright colors—gray, yellow, green, pink, and lilac."[a] Throughout much of this area there are some hundreds of feet out of the total width of the Lykins belt where beds of such colors could easily be concealed. However, with the exceptions already noted, it is doubtful if anything but ocherous reds reach the north end of the area mapped.

The brownish-red sandstone at or near the top of the series (the dull-yellow, thin-bedded sandstone noted above does not appear everywhere) has a variable thickness. It is more than 100 feet thick at Fourmile Canyon. While primarily a massive sandstone, its exposed ledges weather into shingle-like combs.

"*Crinkled*" *sandstone.*—The persistent band which is here referred to as the "crinkled" sandstone is one of the noticeable features of the series. At places it reveals the presence of the Lykins

[a] Op. cit., p. 56.

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where all other beds are covered by the abundant talus of the red rock and Lyons sandstone. This band, nowhere above 35 feet thick, is present wherever the Lykins is found. Its superior hardness causes frequent exposures where the ocherous sandstones above and below it are buried under waste. Such a line of exposures is everywhere found at a nearly uniform distance east of the Lyons sandstone outcrop. It is in the main a sandstone more or less calcareous. Locally it has a bed of dense limestone at its base and sometimes other limestone beds above. Some of these have been quarried for lime. It is of a light-pink or purplish color, clearly and minutely laminated. These laminæ are almost universally deformed, are closely crumpled, and serve to make prominent the effects of a north-south stress which has at places minutely brecciated the rock. The evidences of such a stress are all but lost in the softer massive rocks which are conformable with this layer above and below.

## JURASSIC SYSTEM.

### MORRISON FORMATION.

*Limits.*—At the top of the brownish sandstone above mentioned there is an abrupt change to light colors, or at most there may be about 20 feet of beds of intermediate character. The sudden transition is readily seen at many places and is the convenient indication of the division between the Lykins formation and the Morrison, as the overlying Jurassic beds are called. The upper limit of the Morrison is quite as clearly marked by the hard sandstones and conglomerates of the Dakota, but the body of the formation shows considerable variation from place to place. Its maximum thickness may be taken at a little less than 400 feet (as at Bear and Fourmile canyons).

*Generalized section.*—Sections of the Morrison at various places in this area differ greatly. In the main, however, the formation contains a large proportion of light-colored clays, some moderately indurated and others of flinty hardness, much gray sandstone, often calcareous, and at various horizons beds of highly compact limestone. A very much generalized section would present the beds in about the following order, beginning at the base: Sandstone, clays, limestone, clays. The first and last members of the series are persistent, but the intervening clays and limestone may show two or three alternations and may inclose prominent sandstones.

The thickness of the important sandstone at the base is nowhere less than 10 feet, and may be twice that amount. This bed is persistent and massive, and yields the white building stone commonly known as the "Doctor Bond sandstone." It is slightly calcareous, as are the Morrison sandstones in general. In Bear Canyon it forms the

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western one of two strong ridges. This sandstone is everywhere overlain by soft beds which are covered by waste.

The lowest limestone is at places within 15 feet of this basal sandstone. At South Boulder Canyon there are 40 feet of it in one stratum, but at Bear Canyon it is separated into two strata by a massive sandstone. Near Altona there are three distinct limestones, the topmost being a resistant stratum 30 feet thick which may form the crest of the ridge where the Dakota ledge is locally lower. This is the case for a considerable stretch between Fourmile and Sixmile canyons. These limestones are exceedingly compact, and turn brown upon the slightest weathering, though they are normally a dark bluish gray. As the beds are much fractured or affected with incipient fractures, the brown color is so general, even in fragments broken by the hammer, that the normal gray may easily be overlooked. The sandstones above the basal bed are (1) the resistant beds between the limestones and (2) the Saurian sandstone described by Eldridge for the Denver basin.[a]

South of Boulder the intermediate sandstone beds are represented by the eastern one of the two ridges in Bear Canyon. The rock of this ridge differs little from the basal stratum. North of Boulder these beds, whether one or two, have a characteristic purplish hue, an irregular, often closely laminated bedding, a flow-and-plunge structure at places, and a wavy or scaly appearance where split along bedding planes. Where the sandstone shows this phase it may be very hard. Occasionally the crest line of the bold Dakota hogback jogs to the west and follows one of these strong ledges of the Morrison. This occurs at several places south of Altona.

The next 75 or 100 feet are everywhere obscured in this district. The space is doubtless occupied by the "Atlantosaurus clays" described by Eldridge, but their character can only be inferred from exposures farther south beyond this field. Above these softer beds, which do not outcrop, are limestones generally interbedded with clays.

The horizon above the zone of intermittent limestones is marked by a rather persistent sandstone. It is generally calcareous and stained with iron, the coloring usually taking the form of round dots, in general about the size of shot. When so marked it strongly resembles certain strata of the Dakota, but is distinguished from the latter by the fact that it effervesces with acid. The stain is not always distributed in this way, but may give an irregular rusty color to the whole rock. This is the "Saurian sandstone" described by Eldridge, but no animal remains have been found in this field. Its greatest measured thickness here is less than 15 feet.

[a] Eldridge, G. H., Geology of the Denver basin: Mon. U. S. Geol. Survey, vol. 27, 1896, p. 61.

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The remaining rocks at the top of the Morrison are dense, hard clays and argillaceous sandstones. They are green, yellow, and purple, and occur in beds that are from a few inches to a few feet thick. The fine-grained indurated rocks are full of fractures and tend to crumble into minute angular fragments. Some beds are calcareous. The thickness of these clays is about 30 feet at South Boulder Canyon and nearly three times that amount at Fourmile. They are well exposed on the south side of Bear Canyon, where they are 75 feet thick.

## CRETACEOUS SYSTEM.

### DAKOTA FORMATION.

Above the Jurassic comes the prominent Dakota formation, easily recognized and well known in the great hogback which parallels the Front Range for hundreds of miles. It is a firm sandstone that is often quartzitic, is generally thick bedded, and is characterized by frequent cross-bedding and ripple marks. Its more resistant, heavy beds may give to the hogback one, two, or even three constituent ridges or combs.

*Basal conglomerate.*—At is base, though not everywhere present, is a pebble conglomerate. The constituent pebbles include "abundant limestones, quartzites, clays, flints, jaspers, and rocks of granitic composition, together with the separate mineral constituents of the last."[a] The whole is so firmly cemented that, where unweathered, the rock fractures in broad planes which pass through the pebbles. Frequently a series of thin pebble beds in a mass of sandstone takes the place of the continuous conglomerate. This alternation of beds makes the thickness of the basal zone indefinite, but there are few pebble beds above the first 20 or 30 feet.

*Character of the sandstone.*—Considerable variation may be discerned in the sandstone, but with the exception of the basal conglomerate no one bed has a constant position in the column. Generally the sandstone is composed of quartz grains, with a siliceous cement, and is gray or yellowish gray. With increase of iron oxide the sandstone exhibits striking features of differential coloring. The most common of these is due to the concentration of the iron into evenly distributed spherical specks, which are of uniform size in a particular bed, but which are as small as small shot in some beds and as large as peas in others. The color of these specks is light brown, but in a weathered crust of such a rock it is often bright red, due, no doubt, to the loss of water from the iron oxide. This dotted coloring is exceedingly common, perhaps more so in the upper portion than in the lower. Frequently, also, the weathered surface of a Dakota

[a] Eldridge, op. cit., p. 63.

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block or ledge is blackened by a smooth or even shining crust of manganese and iron oxide.

At intervals between the stronger ridge-making ledges occur layers of thinly laminated shaly sands, aggregating in thickness only a few feet. These crumble out in small angular fragments and their wasting accentuates the relief of the strong ledges. Fire clay is not found in this area. Fragments or impressions of wood are not infrequent, but good fossils were not observed.

*Columnar jointing.*—Some of the upper beds have a distinct columnar jointing. At Sixmile Canyon certain thin ledges when viewed from a short distance look like sheets of basalt. The bedding faces of these same strata are exposed and resemble a rough pavement of polygonal blocks. This jointing produces irregular columns from 2 to 8 inches in diameter. These beds are not to be confused with the igneous rocks, which are intruded.

The line between the Dakota and the overlying Benton shales, while very distinct in a large way, is not so easily located in detail. Alternations of sandstone and shale occur over a zone of 50 feet or more. The thickness of the Dakota at Bear Canyon is about 320 feet, and at Fourmile Canyon a little greater.

### BENTON FORMATION.

*Shales and limestone.*—The Benton shales have a thickness of more than 500 feet at the north end of the field. They are somewhat thinner at the south end and taper uniformly from both ends toward Boulder Creek, where the formation almost disappears. The great body of the shale is dark. There are frequent layers a few inches thick which are strongly impregnated with iron. The formation is calcareous in varying degree. At many places some beds are composed of a black limestone showing a crystalline surface when broken and having a strong bituminous odor. Six miles north of Boulder several hundred feet of the upper strata have this nature. Elsewhere this phenomenon seems to be confined to isolated beds.

*Upper beds and Niobrara contact.*—As the summit is approached the blackness disappears and the last 75 feet (observed near the north end of the field) show light-colored limestone, shale, and sandstone. North of Sixmile Canyon these beds, which may be regarded as transitional to the Niobrara, show the following section:

*Section of upper part of Benton formation north of Sixmile Canyon.*

| | Feet. |
|---|---|
| Greenish sandstone, calcareous in upper third | 15 |
| Shales, blue to yellow, noncalcareous | 15 |
| Sandstone, noncalcareous, firm, rather purplish | 10 |
| Shale, iron stained at intervals | 10 |
| Shale, calcareous (or calcareous at top). | |

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Below these beds is a limestone of variable thickness strongly resembling the basal Niobrara. It occurs in lenses only.

The greenish sandstone at the top is found below the basal Niobrara wherever the latter is exposed in this district. It is generally 10 or 15 feet thick, and is not calcareous except in the upper portion. As it is often very much fractured and the cracks are abundantly filled with carbonate of lime, this calcareous character may be due to infiltration from the limestone above. The blue and yellow shales below are also seen wherever the base of the greenish sandstone is exposed.

### NIOBRARA FORMATION.

The Benton is succeeded by the Niobrara, whose prominent characteristic is its calcareous nature. It is composed in small part of true limestones, but the greater mass is made up of calcareous shales, while considerable portions are of intermediate character. Its thickness at Fourmile Canyon is a little more than 400 feet.

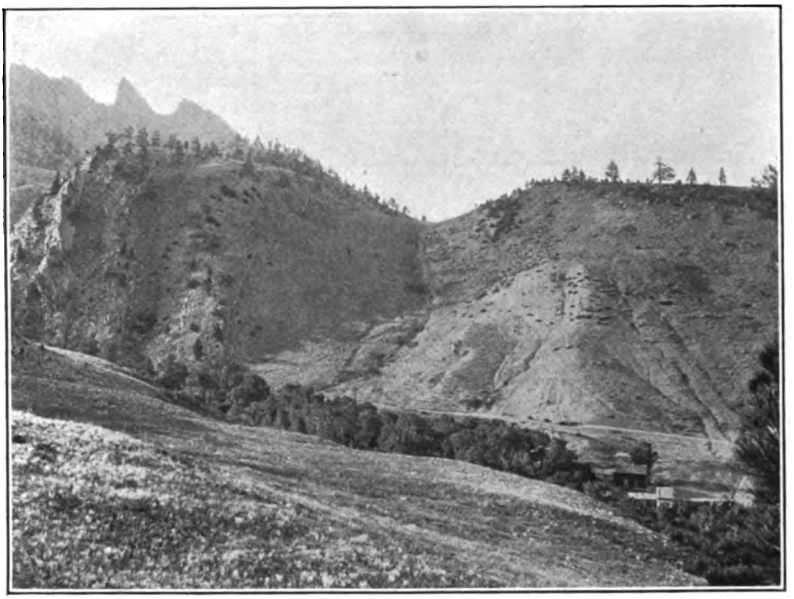
The basal stratum of compact limestone rests upon the greenish sandstone which is at the top of the Benton. Occasionally a foot or more of light-colored marl intervenes. Below the Niobrara, as pointed out above, are occasional beds of similar limestone and calcareous shales interbedded with noncalcareous sandstones. In lithological character these transitional beds resemble the Benton more than the Niobrara. The faunal relations are not decisive. It is therefore convenient from a field standpoint to adopt the above-named horizon as the dividing line between the Benton and the Niobrara because of the sharp change at this horizon from a sandstone to a compact limestone.

*Basal limestone.*—This is generally about 15 feet thick, reaching a probable maximum of 20 feet; it is light gray, dolomitic, and very compact; it breaks with a conchoidal fracture. Its individual beds may be 2 or 3 feet thick and are sometimes separated by thin layers of clay. The bedding is irregular and a 3-foot bed has been seen to pinch out within 10 feet. It abounds in shells of *Inoceramus* and has also some dendritic markings. On its upper side it passes into the calcareous shales through an alternation of thinner limestone and shale beds. These thinner limestone beds are characteristically jointed into small blocks whose edges are rounded, and when exposed in the quarry the bed has the appearance of a pavement.

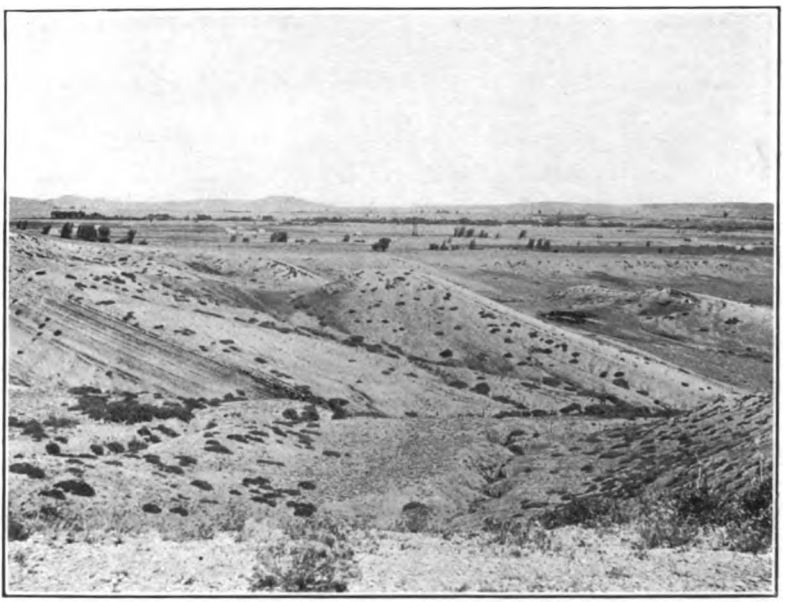
The basal limestone has been frequently overturned (see p. 50) and has been much crushed by lateral stress. In outcrops it is by far the most prominent stratum between the Dakota and the Laramie, except where the Hygiene sandstone makes its prominent ridge.

*Shales.*—Most of the Niobrara shales are dark brown, but their outcropping edges weather light gray, sometimes almost white. The top-

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*A*. VIEW NORTHWARD ACROSS MOUTH OF BEAR CANYON.



*B*. OUTCROPS OF NIOBRARA SHALES.

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most beds, which are 10 or 20 feet thick, are of a much lighter brown, and weathering gives to them a characteristic yellow color. These are highly calcareous, and pass at places into impure limestones, 5 or 6 inches thick. This horizon is frequently marked by a ridge. Generally, too, about midway between base and summit, the dark shales which weather white contain harder and more calcareous beds, whose outcrops make low ridges (Pl. V, *B*). Locally these also are impure limestones. In this zone are beds several inches or even a foot thick composed entirely of *Ostrea congesta* shells. More than one of such zones occur at places. As in the basal limestone, the rock has a strongly bituminous odor when struck, especially where fossils are present.

### PIERRE FORMATION.

*Color.*—Above the Niobrara are the Pierre shales, which are more than 5,000 feet thick. They are slate colored, leaden gray, dark brown, and sometimes nearly black. Weathering gives to them a greenish-drab hue, which, at any considerable distance from the foothills, is their color to a depth of 30 feet, more or less. It is therefore the one ordinarily seen. Near the base of the formation, however, just in front of the hogbacks, erosion is more active and the shales are often seen with their original dark colors.

*Limestone beds.*—While in general noncalcareous, the Pierre has local limy beds. At places these form continuous strata, as, for example, 4 miles north of Boulder, one-half mile east of the contact with the Niobrara. Here, for a thickness of nearly 40 feet, strong limestone beds are so closely grouped as to give the outcrop the appearance of the basal Niobrara. At other places the limestone beds are smaller and more isolated, or are divided into concretionary masses often containing fossils. Less prominent calcareous masses may be found at any horizon either in beds or in more or less perfect concretions.

Concentrations of iron occur in similar but less massive forms, ranging from clear-cut beds to well-formed nodules. The lime and the iron may or may not occur in the same concretionary mass. Many of the calcareous nodules mentioned contain much iron carbonate, which, in progressive oxidation toward the center, gives rise to sharply marked concentric shells differing in color.

*Hygiene sandstone member.*—Sandy beds may occur at any place in the section. The most prominent and persistent of these is about one-third way up from the base, or a little higher. Its outcrop is chiefly at the north end of the field, where it forms a considerable ridge, though disappearing under Table Mesa. Where it reappears north of this broad mesa its outcrop again forms a strong ridge, which is almost continuous for many miles. The ridge passes

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within a mile and a half of the village of Hygiene, where the sandstone is typically developed. The name Hygiene sandstone has therefore been adopted for this member of the Pierre formation. To the public it has become well known on the Culver ranch, 6 miles southwest of Berthoud, where it crosses Little Thompson Creek and where a seepage of oil has long been known. At its outcrop west of Berthoud it has a thickness of several hundred feet. At the north edge of the area described in this report it has a thickness of 250 feet. At Bear Canyon is an isolated outcrop of an equally prominent sandstone, 150 feet thick, which is probably of Hygiene age.

The Hygiene sandstone is thick bedded and frequently cross-bedded. Much of it is dark greenish gray and gritty. The remainder is light gray. The whole is calcareous where fresh. It loses its lime in weathering, takes a paler-greenish tint, and becomes friable. It frequently contains carbonaceous matter resembling small sticks of wood turned to coal. It also contains fossils of invertebrates, but its fauna is not yet known to be distinctive of this horizon.

Near Boulder the Hygiene sandstone is within less than 1,000 feet of the base of the Pierre and is itself a very thin stratum. It thickens greatly toward the north, as do also the shales which lie below it. Five miles north of Boulder the underlying shales, which are 1,000 feet thick near Boulder, have a thickness of about 2,700 feet. Here also the sandstone begins to separate into two strata by the coming in of a shale parting. In the next 2 miles this intercalated shale becomes 200 or 300 feet thick. In so far as the upper sandstone can be identified north of Table Mesa, the indications are that this intervening stratum goes on thickening to the north, in common with other strata.

From these pure sands at one extreme to pure clay shales at the other, the Pierre shows all gradations in composition. The sandy layers are generally firm and gritty, almost as dark colored as the shales themselves, and not very porous. In rare instances light-colored, friable sands are encountered in drilling oil wells.

The thickness of the sandy beds is as variable as their constitution, while the lateral extent of such beds, as indicated by occasional outcrops and by the records of wells, is, in a large majority of cases, a small fraction of a mile. Some of these beds may be lenses, but doubtless the more common mode of lateral limitation of the sands is by a gradual change in composition of the beds into the shales. Such beds are found at irregular depths. As some of them disappear and others come in, their depths vary greatly from place to place.

The upper division of the Hygiene sandstone is characterized by large calcareous concretions several feet in diameter. Where the outcrop appears as a low ridge or only a stony band, these concretions,

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crumbling, form isolated rocky patches of angular fragments, frequently showing fossils. The exposures of beds of this description in or near the area described in this report are insufficient for the correlation of their outcrops, or even for the determination of their number. It seems necessary to assume, however, that there is more than one bed, and it is probable that the beds occur at any horizon and are of very limited lateral extent. The upper division of the Hygiene sandstone is here given as a typical case, except that it has far greater continuity than others of its kind. Whatever may be true of these calcareous beds, the sandy beds, except the main stratum described above, are distributed through the column of shales at irregular intervals and are generally of small extent.

### FOX HILLS FORMATION.

Within the limits of this area the great body of the Fox Hills is but indefinitely distinguished from the Pierre. In mild contrast with the latter its shales are yellowish instead of slate colored, and are also more arenaceous. This latter quality is plainly shown in the soil produced. At some places the transition zone spoken of by Eldridge[a] as marked by "limestones and small ferruginous nodules" is plainly seen. No attempt has been made to trace on the accompanying map the contact between these two formations, as definite points of contact are infrequent and separation of the areas of the two terranes in a detailed way must in fact rest largely on the character of the soils. This distinction is frequently masked by outwash from the foothills.

The topmost stratum of the Fox Hills is, however, a very definite feature in the stratigraphy. For many feet below it there are occasional sandstone beds, and the intervening shales are highly sandy, but at the top is a continuous bed of sandstone 40 feet thick. It is best exemplified just east of the area mapped, where a fine fault brings it up to view alongside the basal Laramie. The sandstone is here fine grained and yellow, very slightly calcareous, and incloses great calcareous, iron-stained concretions. The entire thickness of the Fox Hills near Niwot is about 1,300 feet.

### LARAMIE FORMATION.

The Laramie outcrops in the southeast corner of the area. Within the limits here defined this formation consists essentially of (1) sandstones at the base, (2) sandstones alternating with shales and coal overlying, (3) sandstones above the coal, and (4) clays containing isolated sandstone beds and lignitic streaks.

[a] Mon. U. S. Geol. Survey, vol. 27, p. 71.



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*Basal sandstones.*—The basal sandstones are exposed at various places in the Marshall coal field, but best of all at White Rocks, on the eastern border of the area mapped. Here the bold sandstone escarpment comprises two distinct and massive beds, whose topographic effect, however, is that of a single stratum continuous with the Fox Hills sandstone beneath. The lower Laramie sandstone is 40 feet thick, equaling the underlying Fox Hills sandstone, while between the two are a few feet of thinly laminated sandstones, varying to a lignitic shale. The second and thicker stratum of Laramie is separated from the first by gray, shaly sands, inclosing 10 inches of lignitic shale and above it 10 inches of coal.

Both Laramie beds are clearly distinguished from the Fox Hills by their gray or white color and coarser grain. They are composed of coarse quartz sand, and in addition always show some black specks of an undetermined mineral. The two sandstones differ in the following respects: The upper is distinctly whiter and, where exposed along bedding planes (and to a less degree on fracture planes), the surface is marked by weathered-out cracks, making polygonal patterns a few feet across. Both strata are weakly cemented and noncalcareous, but contain giant concretions which are very calcareous, hard, and, on weathered surfaces, are stained brown with iron oxide.

*Beds associated with the coal.*—The 75 feet of thinner-bedded sandstones above, containing some shale and coal, are best seen at Marshall. The shales occur at frequent intervals, and are often lignitic. The one workable coal seam is sometimes at the top of this division, but again is overlain by 5 or 10 feet of shales and thin sands; all, however, lie below the more persistent sandstone referred to under (3) above.[a] Aside from the coal seam, no horizon above the basal sandstones is more definite than the *Ostrea glabra* zone, which occurs 15 or 20 feet from the base of the series.

The sandstone above the coal is not unlike the second massive bed above the bottom. It weathers into the same angular patterns, and has the same appearance in the hand specimen. Its thickness is from 8 to 15 feet. The overlying clays, as shown in this area, are yellow and purple, and have frequent lignitic bands but no coal, at least within the limits of the area covered by the map.

## QUATERNARY DEPOSITS.

There are no deposits younger than Laramie except the uncompacted mantle rock. This is the coarse mesa gravel (see p. 14), or finer alluvium, similar to the deposit formed by the present streams.

[a] The sandstone "C" of Eldridge, op. cit., p. 74; also p. 346.

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In the eastern part of the area, especially in the northeastern corner, are patches of loam which plainly belong to the western margin of the great sheet which covers the surface a little farther east. This is the "loess" of Hayden and Aughey[a] and of Emmons.[b] Just what relation these patches bear to the "Plains marl" of Hay,[c] or the great silt body of the Plains Tertiary,[d] was not determined on account of the narrowness of the area studied.

The whole surface east of the foothills is, in a large way, a patchwork of stream terraces. The oldest surficial deposits are highest and farthest from the larger streams, and there is a decrease in age from those at the top of Haystack Mountain to the recent alluvium. No other time scale is suggested by the phenomena of this portion of the plains than that based on relative altitude and distance from streams. In large part, at least, these deposits are of Pleistocene age, though the time of their beginning is not definitely fixed.

## IGNEOUS ROCKS.

The igneous rocks are of interest chiefly with reference to their manner of occurrence and relations to the deformation of the sedimentaries, rather than to their character. Constituent minerals and rock textures are therefore given very brief and summary mention.

### ROCKS OF THE ARCHEAN AREA.

The Archean rocks are in general granite and granite-gneiss. The texture is generally coarse and the color very frequently pink on account of the pink orthoclase contained. These rocks are cut by numerous dikes, which are of all sizes up to a maximum of many miles in length and 50 or more feet wide. Their texture is as varied as the dimensions of the dikes. In direction the larger dikes show a tendency to approximate parallelism with the foothill outcrops—that is, with the axis of the foothill monocline. They would, however, if prolonged to the south, meet the foothill belt at a small angle. Their most prominent direction, therefore, is more nearly that of the axes of the échelon folds which branch out from the foothills. This comparison of the general directions of two sets of features of different age is used as a mere convenience in description; it is not intended to affirm a genetic relation.

One of these dikes passes through Orodell, 2 miles west of Boulder. It passes up the valley of Fourmile Creek for a mile north of that

[a] Eighth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., 1874, pp. 245–255.
[b] Mon. U. S. Geol. Survey, vol. 27, 1896, p. 261.
[c] Water resources of a portion of the Great Plains; Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1895, p. 570.
[d] Johnson, W. D., The High Plains and their utilization: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1901, p. 653.

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point and goes far to the north-northwest. Its southern end is somewhat interrupted, but its general course is in line with that of the Green Mountain fault (p. 46). The "Hoosier dike," of the same kind, lying 2 miles farther west, is even larger and more continuous.

### INTRUSIVES OF THE FOOTHILLS.

In the sedimentaries the intrusion is commonly in the form of sheets. There are also series of apparently disconnected bosses, but these are ranged in lines following the strike of the strata, three or four appearing at about the same horizon within a mile.

There are here no intrusives in the foothills south of Gregory Canyon. Within the narrow limits of the area mapped, at least, such intrusion is limited to the areas of complex folding—that is, it shows a marked association with échelon folding. The greatest sheets occur at the north end, where such folding is shown on the largest scale. In view of the association of certain intrusive rocks with small deformations, the presence of similar rocks beyond the limits of the area here described may well be noted and taken tentatively as a suggestion of the presence of folds. The large importance of these minor folds in the structure of the adjacent oil field gives significance to such associated features. (Compare p. 93.)

### SUNSHINE DIKE.

A large dike, 1 mile long and from 15 to 40 feet wide, follows the south side of Sunshine Canyon. A short distance beyond its western end is a similar dike that runs north-northwest parallel to the Orodell pegmatite dike for a mile and then trends northwest in an irregular course to the Orodell dike. The small interruption may be disregarded, and both dikes are here called the Sunshine dike. This dike is crooked and branching, and at places there are two or three parallel dikes, as if the main one were subdivided. The rock of this dike has a dense greenish-gray felsitic groundmass. It contains phenocrysts of quartz, feldspar, and mica, any of which may be one-fourth of an inch in diameter. The proportion of the volume of phenocrysts to that of the groundmass varies greatly. Locally the phenocrysts may constitute half the rock.

### FLAGSTAFF SHEET.

On the east side of Flagstaff Hill and near the base of the red rock is an intrusive sheet of the same character as the Sunshine dike. It extends north from Gregory Canyon to within half a mile of Boulder Creek. North of that stream the sheet reappears at the same horizon, and continues a mile to the north. Its greatest width is at least 40 feet. The exact contact on its east side is seen in the Silver

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Lake ditch, one-fourth mile north of Boulder Creek. The red rock has here been greatly altered by the heat and both rocks have been much weathered by spring water following the contact.

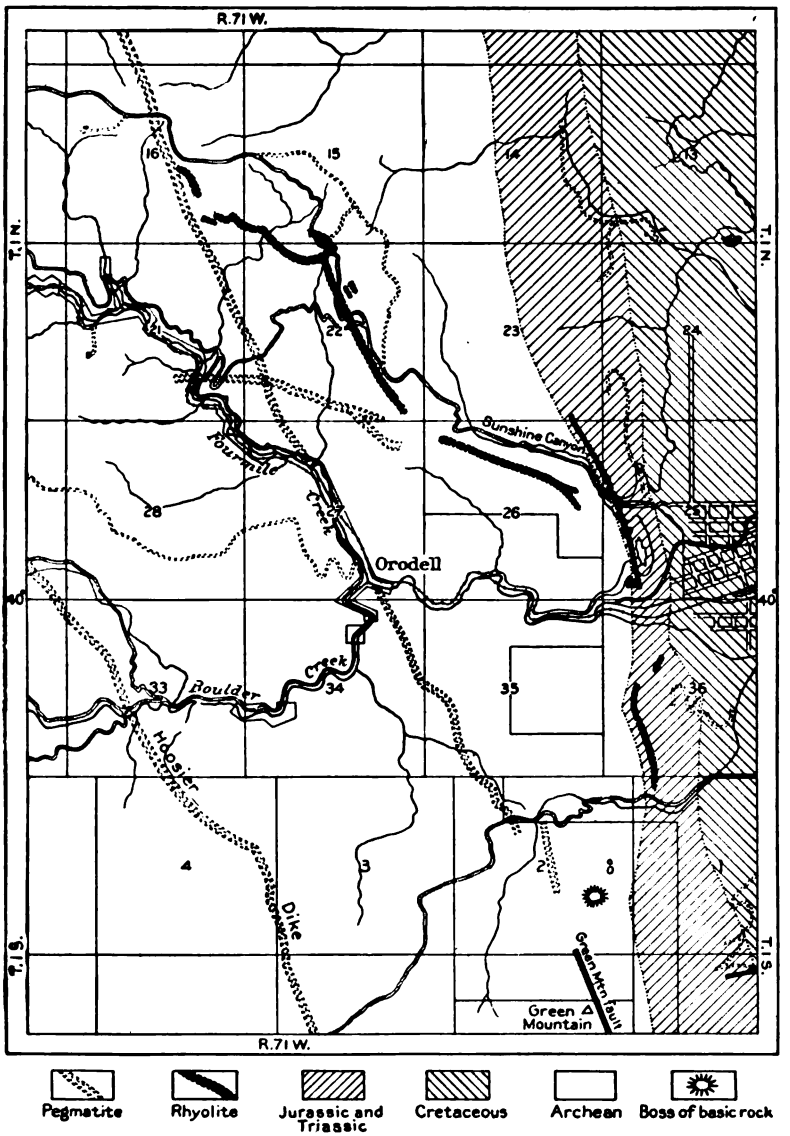



FIG. 2.—Map showing dikes and intrusive sheets west of Boulder. By Hugh F. Watts.

At the north end of Huggins Park is a small offshoot from the main Flagstaff intrusion, or, it may be, merely a dislocated portion of the larger mass involved in the eastward slipping of the red rock. Just below the Huggins Park intrusion is an exposure of the Dakota

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sandstones and shaly sands, apparently altered by heat. On this account it is presumable that this small intrusion followed a separate fissure which conducted it to a higher horizon than that of the larger sheet on the west.

#### PLUMELY CANYON SHEET.

A large sheet of rock similar to that at Flagstaff is intruded in the red rock in Plumely Canyon, a western tributary to Lykins Canyon, at the north end of the area mapped. This is fully 30 feet thick and has thoroughly baked the including strata of arkose sandstone, giving them a black color and a siliceous appearance. Minor beds and pockets of shale in the sandstone have been much more affected by the heat than the latter. Pockets of shale are baked and blackened where the including feldspathic sandstone is unchanged.

#### ALTONA SHEET.

A larger sheet of the same nature, having at places a width of 100 feet, occurs at or near the base of the Lykins, above the Lyons sandstone and below the ocherous shales. The exposure of this sheet begins at a point west of Altona and extends 2 miles to the north without interruption. For much of its length it forms a prominent ridge on the floor of the large longitudinal valley which has been cut out on the Lykins shales.

South of Altona a 20-foot sheet of the same rock is intrusive near the top of the Lykins. The sandy shales have been greatly altered by heat. Their color has changed from red to black, and some of the shales so strongly resemble lavas that they might be mistaken for such if gradations were not apparent. The contacts of this sheet are far from regular, the magma having run out in small branches, sometimes surrounding blocks of the country rock.

All of these sheets are similar in character to the Sunshine dike described above, though varying greatly in details of texture. All are distinctly porphyritic, though the proportion of phenocrysts to the entire mass is subject to much variation. The very fine-textured groundmass is characteristically green or greenish gray, giving color to the whole rock.

#### INTRUSIVE ROCKS IN THE DAKOTA AND BENTON.

The Dakota contains intrusives at various places in the northern part of the area. In Sixmile Canyon there are three sheets with an average thickness of 10 feet, and the same rock appears at intervals for 2 miles farther north. It appears in sheets at various places in sec. 25, T. 2 N., R. 71 W. On the north side of sec. 36 of the same township it occurs as a boss which has greatly altered the Dakota

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rocks which it intrudes. The intrusives in the Dakota and those in the Benton, which are very similar, differ little, except in color, from those in the older strata. Those in the Dakota and Benton are a dull gray.

A line of bosses occurs near the base of the Benton shales. The most northerly and largest one is in sec. 25. This irregular mass, together with the dike which runs eastward from it, traverses almost the entire width of the Benton strip, which is nearly one-half mile wide at this place. This fissure crosses one of the most prominent of the échelon folds of the foothills. (See fig. 3, p. 44.) The largest boss is centrally located in a group of such folds.

### INTRUSIVE ROCKS IN THE NIOBRARA AND PIERRE.

Near the contact of the Niobrara and the Pierre and within a mile north of Boulder is a line of small volcanic knolls. The igneous rock which forms these knolls may be seen at four places. It occurs at the Colorado Sanitarium, near the mouth of Sunshine Canyon, at the base of the Niobrara. At this place it was thrown out from a small excavation and does not cause any topographic feature. One-fourth of a mile to the north it makes a low knoll 500 feet in diameter extending across the Niobrara and into the Pierre. A second and similar knoll occurs 600 feet farther north, this one being entirely within the Pierre. A little north of the middle of sec. 24, T. 1 N., R. 71 W., is another knoll, similar in every way to the other two.

No sheet connecting these four masses has been found, but as they are ranged along the strike of the strata and are all composed of the same rock, they belong undoubtedly to a common magma, which at this horizon became separated along at least four lines of slight resistance. The rock at this highest horizon contains comparatively few crystals. Large masses of it are nearly white, purely felsitic lava.

### DIFFERENCES IN FORM OF INTRUSIONS.

From the Fountain sandstone to the shales of the Pierre the sheets become progressively more irregular in continuity and thickness. The thickness of the sheets is almost uniform throughout the Fountain sandstone, but varies in the Lykins. In the Dakota the intrusive sheets have but limited extent and there is a strong tendency for the igneous masses to be concentrated into bosses. In the Benton such localization is the rule. All the intrusives in this formation appear now as isolated knolls, except in the one instance described above, where a dike runs eastward from the largest of such knolls. In the Niobrara and Pierre all igneous rocks appear as completely isolated and well-spaced knolls with no evidence of connecting

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sheets. The association of all these igneous rocks with the échelon folds suggests that both the intrusion and the folding occurred during the same process—that is, during the formation of the great foothill monocline.

### VALMONT DIKE.

The basic igneous rocks of this area are represented by only one prominent formation—the Valmont dike.[a] This is a great mass of dolerite. Both its occurrence and its petrographic character have been described in detail by Whitman Cross.[b] It has a maximum width of 45 feet and an extreme length of nearly 3 miles, though it is not uninterrupted. From the village of Valmont it extends east by north uninterruptedly 1 mile and as a series of knolls for another mile. For 1 mile west of Valmont it does not appear, but at that distance, in an almost straight line with its course, is a knob of the same rock. The main portion forms a ridge, which rises at Valmont more than 200 feet above Boulder Creek, but which is now being cut away for road material.

This dike is of an even-grained dolerite, divided into large blocks by joints which run parallel and transverse to its length. Within a few inches or a foot of its walls the rock may be divided into thin plates by numerous joints parallel to the bounding surface. In a very narrow zone next to the contact the rock may have a lava-like appearance, but at a distance not greater than a very few inches the characteristic uniform texture of the dike appears.

The stratified rocks containing this dike are (except in case of the isolated knoll to the west) the Fox Hills shales. There is nothing more striking in the whole occurrence than the small degree of alteration which these shales have undergone. Beyond a very little hardening it can not be said that they have been changed at all. In this inference, however, the subsequent weathering is not considered. The vicinity of the contact has doubtless been subject to the work of percolating water. Along the vertical joints of the dike near the contact there have been much weathering and some deposition of calcite.

It is inferred by Cross[c] that this dike "represents a channel through which the basaltic magma rose to the surface;" that this eruption occurred during the Denver epoch; and that strata, since

[a] One-half mile north of Green Mountain there is, surrounded by the granite, a small isolated mass of a peculiar nearly black igneous rock, with large phenocrysts of several kinds. This knob was located and specimens were collected from it by Mr. Hugh F. Watts, to whom the writer is indebted for information and specimen. The rock is unlike any other known within the area.

[b] Bull. U. S. Geol. Survey No. 150, 1898, p. 261; also Geology of the Denver basin: Mon. U. S. Geol. Survey, vol. 27, 1896, pp. 280 and 298.

[c] Bull. cit., p. 261.

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denuded, made the surface of the ground about 2,000 feet higher then than now. The nearly complete uniformity of texture from wall to wall is taken to indicate that the magma cooled at a very uniform rate and that the adjacent shales had been thoroughly heated by long-continued passage of lava.

At Burnt Knoll, 3 miles northeast of Marshall, are rocks which bear a remarkable resemblance to lavas. The zone characterized by this appearance is horizontal and confined to the top of the hill, though much of the material has rolled down and now clothes the sides. Apparent injection among fragments of baked shale is the most common phenomenon, but nothing of undoubted volcanic origin has been found. The coal beneath the hill is nowhere affected by heat. Gradations from the most lava-like appearance to ordinary shale indicate that the phenomena are due to heat alone and not to injection. Doubtless the heat came from the burning of associated coal beds, probably ignited by prairie fires.[a]

## STRUCTURE.

### FOOTHILL MONOCLINE.

The master structural feature of this region is the great upturn of the strata against the mountain range. The form and magnitude of this fold appear most striking when the Archean surface alone is considered. As shown under the heading "Physiography," the first Archean belt west of the foothills is a dissected plateau 10 to 12 miles wide, which slopes east and abuts against the mountain ridge proper on the west. It is from 6,500 to 7,000 feet above sea level at its eastern edge, where it ends abruptly and is flanked by the Fountain sandstone, which has an average dip of about 50°. The height of this sloping face above the plains is nearly 1,000 feet, but this is a small fraction of the true height of the monocline. Five miles east of the base of the foothills the Archean surface is at least 9,500 feet below the surface or 4,200 feet below the level of the sea. The real face of the granite plateau is therefore about 2 miles high, and this enormous rise is accomplished in 6 miles. These figures represent merely the measured thicknesses of strata outcropping in the first 5 miles from the foothills. They do not take into account the possible thinning or thickening within that distance, nor the probable presence of other beds overlapped by those exposed.

The granite plateau on the west shows no evidence of any deformation since its elevation above base-level. The uplift therefore resulted in the formation of an almost simple monocline not less than 2 miles high and 6 miles wide. But it does not follow that this flexing

a See also Eldridge, op. cit., p. 75

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was brought about entirely by the mountain-making forces. In fact, the greater part of it was apparently accomplished while the thick formations were being deposited to the east and land continued to the west. When the topmost marine stratum, the Fox Hills, was laid down in the shallow water, the elevation of its surface probably differed little from that of the granite terrane to the west. The same statement would be fairly correct for the lowest stratum of the Fountain sandstone during its deposition, and for any intervening bed. While at any time during the long process of sedimentation the last-laid stratum was approximately horizontal and close to the sea level, the originally (nearly) horizontal granite base was getting constantly lower, and its eastward or seaward dip near shore was correspondingly increased.

It follows from the above that before the present Rocky Mountains were formed, and while the area now included in them was close to the sea level, there had been produced a monoclinal fold whose height was but little less than that which would now appear in the granite surface if the sediments were removed. This conclusion involves no hypothetical premise except the generally accepted continuance of land conditions on the site of the Front Range of the Rocky Mountains.

In determining the height of the monocline it must be remembered that the land surface on the west was constantly being lowered by erosion. Occasional or continuous uplift was necessary in order to furnish the material for the sedimentary formations. The amount of flexing is, therefore, the sum of the subsidence of 9,500 feet on the east and an unknown elevation on the west. This rising on the west might even be equal to the sinking on the east, hence the actual height of the flexure is but partially represented by the 2-mile vertical interval between the exposed surface of the Archean west of the foothills and its buried surface under the plains. The total amount of flexing is equal to the offset that would appear if the denudation west of the hinged shore line had not taken place and the sedimentary formations east of that line were removed.

If the above statements are correct the influence of actual mountain making in increasing the height of this monocline was comparatively small. It is, however, conceivable that an east-west compressive force may have accentuated the fold along the steepest part of its slope, thus tending to narrow the belt of dipping strata, while their dip was at the same time steepened. The slope of the monocline previous to the mountain uplift can not be determined unless the shore line is definitely located, which is probably impossible. No reason appears in this area, however, for departing from the common assumption that the sea did not cover the line which is now the axis of the Front Range and which lies a few miles to the west.

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It is not conceivable that mere sinking under an increasing load of sediments should have folded the rocks so sharply or along a belt so narrow as the present monocline; yet the height of the flexure is mainly due to that cause. It is only in association with the last and smaller part of the deformation that lateral compressive force is evident. The process of mountain making gave to the granite plateau west of the foothills a comparatively small relative uplift above the plains.

## ÉCHELON FOLDS.

Other definite effects of lateral compression are seen in a special type of folding known as "échelon," which at places accompanies the foothill uplift. Such folding indicates that there was a north-south pressure in addition to the dominant east-west pressure. The resultant stress was in lines a little north of east and south of west, causing folds whose axes diverge slightly from the foothill belt, and trend south by east. Within this area such folds are all small. In general, however, such folds are larger in the younger and eastern-most strata. They are largest in the Pierre, become less and less marked to the west, and almost die out by the time the Fountain sandstone is reached. This general rule is not without its exceptions, because the size of such folds is also in a measure dependent on the strength of the strata affected. They are therefore larger and rather more prominent in the weaker Jurassic than in the stronger Dakota above it. Wherever a stratum of some strength is thus folded the end of the canoe-shaped synclinal trough shows a distinct eminence. All the échelon folds are shown on the geologic map (Pl. II).

### FOLD NEAR SOUTH BOULDER CANYON.

The échelon fold affecting the lowest strata occurs a mile north of South Boulder Canyon. Here the top of the red rock is offset 1,000 feet to the west on the south side of a small stream as compared with the north side. The younger strata to the east are less and less affected, so that the Dakota is offset but 500 feet and the Niobrara is not folded at all. The location of the fold is significant, being, as it is, at the extremity of the South Boulder fault. The two are but different phases of the same feature and are due to the same act of deformation, only the style of deformation differs.

### FOLD SOUTH OF FOURMILE CANYON.

One-half mile south of Fourmile Gulch a mild tendency to this type of folding shows itself in a strong southwest trend of the Dakota hogback, which makes a jog of some 400 feet from its otherwise uniform course. In diminishing degree this fold can be traced

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north-northwest and south-southeast to the Jurassic and Benton, respectively.

FOLD IN SEC. 25, 6 MILES NORTH OF BOULDER.

A large number of small, well-developed folds of this kind appear in secs. 36 and 25, 6 miles north of Boulder. In the west half of sec. 25 a prominent, bald, rounded hill rises several hundred feet above the crest of the Dakota ridge, which at this place is broad and less distinctly marked than usual, though not lower. Here, for a short distance, the ridge-making rock is not the Dakota, but the strong, purplish sandstone in the Morrison. The rounded hill mentioned is at the end of a canoe-shaped structural trough in this sandstone. (See fig. 3.) East of it, in the same stratum, is a well-delineated anticline, with an axis pointing south by east, thus diverging slightly from the main trend of the outcrop. The exposed edge of this stratum first runs north, turns around the synclinal hill, loops back to the south for a third of a mile, and then turns north again around the anticline. All the beds of the Jurassic and those adjacent are strongly affected in similar manner. In a direction north by west the fold affects the Fountain sandstone for a number of miles, flattening its eastward dip of nearly 30° to 7° or 8° along the line of the fold. It is largely due to this flattening of dip that the outcrop of the Fountain sandstone is so greatly broadened at the north end of the area mapped. The effect on this formation is also seen in the northeast trend of its eastern boundary, west of Altona.

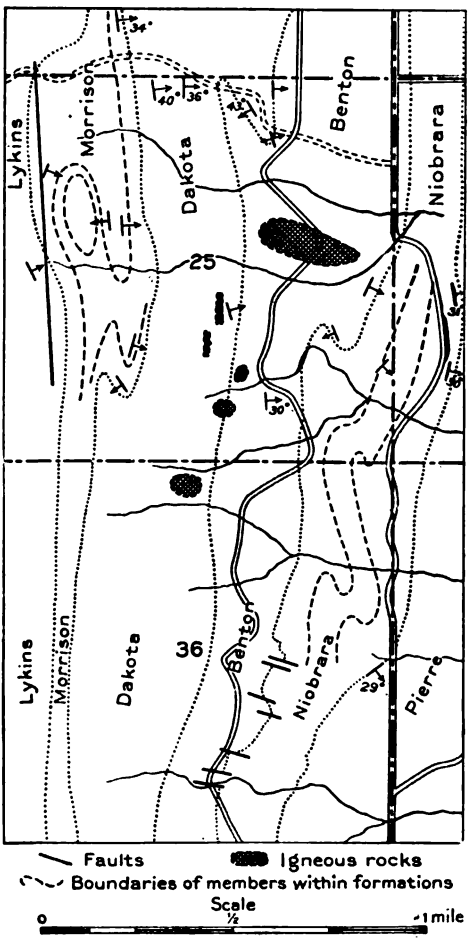



FIG. 3.—Map of secs. 25 and 36, T. 2 N., R. 71 W.

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Near the northern line of sec. 25 the upper beds of the Dakota are distorted by an abrupt fold of the same kind. The outcrop, as traced southward, turns backward to the northwest, but in this instance less than a fourth of a mile. The north-northwest continuation of this fold and the fold above mentioned together produce the flattening in the dip of the Fountain sandstone. The southward continuation of this fold is beautifully revealed in the basal limestone of the Niobrara. The higher, shaly limestones of this series are somewhat folded along the same axis, but seem in the main to have slipped one over another at the place where corresponding folds might have been expected. By such means the site of their folding was shifted nearly a mile to the south. The folds show clearly near the east side of sec. 36.

### FOLD IN THE HYGIENE SANDSTONE OPPOSITE SIXMILE GULCH.

Just as the north-northwest continuation of this group of folds in secs. 25 and 36 causes a flattening of the dip of the red rock, its continuation in the opposite direction has like effects in the Hygiene sandstone of the Pierre. If the line of the northwestern continuation be extended in the opposite direction, it crosses the Hygiene sandstone in sec. 6, T. 1 N., R. 70 W. At this point the outcrop of the sandstone deviates from its general northerly course and trends straight northeast, making an offset of an entire mile within the section. (See map, Pl. II, p. 10.) This is one expression of the tendency to échelon folding. Another is seen in the reduced dip, 18°, as compared with 55° on the south and 25° on the north. If the line of these folds is extended still farther south, it passes a little west of the producing oil wells. The significance of this in the structure of the oil field is mentioned below (p. 87).

### TABLE MESA FOLD.

Two miles north of Altona all strata younger than the red rock strike approximately northeast for several miles, but to the north again following their usual northward trends. In this deformation no such sharply marked échelon folds were developed in the foothill outcrops as are seen farther south. The deformation represented by this incipient fold is, however, large. The effect of the same stress on the Hygiene sandstone was to make a definite anticline whose western limb dips 18° toward the mountains. The sandstone has been eroded from the crest of this fold for fully 3 miles, while it remains in the canoe-shaped syncline west of it. The edge of the Hygiene sandstone is not everywhere exposed, but if laid bare it would make the long loop indicated on the map, west of

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Haystack Mountain. (See map, Pl. II. A detailed description is given on p. 88.) The axis of this anticline, if extended southward, would pass a little east of the producing oil wells. Its significance is discussed below.

## FAULTS AND LANDSLIPS.

In the foothills of this area there are three large faults and at least one small one whose directions differ little from the strike. The three large ones which affect the western margin of the Fountain outcrop are shown plainly on the map.

### SOUTH BOULDER FAULT.

The fault between the two South Boulder peaks strikes south by east from the vicinity of the peaks, but its southerly extension curves more to the east, and it dies out in the incipient échelon fold mentioned above. The downthrow, more than 2,000 feet, is on the west side, repeating the outcrop of the Fountain sandstone and causing two peaks instead of one. (See fig. 1, p. 12.) The two South Boulder peaks will here be spoken of as outer and inner. The outer is made by the main outcrop of the Fountain sandstone. The inner and higher peak is on the fault block of the same formation. It is half a mile southwest of the outer peak.

The fault can be distinctly seen at a point halfway up the valley of the small stream which runs south from the peaks. Here its hade is to the west. As all other features indicate east-west compression in this region, rather than stretching, it is safe to assume that this is a thrust and not a gravity fault. This implies that the hade was toward the upthrow or east side when the strata were faulted, and that it was rotated to its present position by the further tilting of the strata. If made since the strata attained their present position it must be a normal fault, for the present hade is toward the downthrow side. This would indicate stretching, a supposition which is unsupported.

It is difficult to determine how far this fault extends north of the peaks, because its farther extension is in the granite. The block of red rock is not more than 700 feet deep, being limited below by its stratigraphic base, which dips E. 52°, and by the fault plane, which dips west. (See fig. 1, p. 12.) As the gorge leading west from the outer and more northerly peak is much deeper than this, the fault block terminates here and the red rock is not seen farther north.

### GREEN MOUNTAIN FAULT.

Another fault, similar in every respect to the one just described, bears the same relation to Green Mountain as the South Boulder

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fault does to the inner South Boulder Peak. The Green Mountain fault extends south by east from Green Mountain and dies out in the vicinity of South Boulder Peak. Its extension north of Green Mountain is in the granite and is not apparent. The width of the red rock whose outcrop is thus duplicated west of the main exposure is fully 400 feet; the depth of the block is about the same. The block is terminated by the deep valley just north of Green Mountain. The maximum throw of this fault is probably in Bear Canyon, and is apparently less than that of the South Boulder fault. The granite strip between the duplicated outcrops of the red rock is occupied by streams, as in both the other cases of similar faulting in this area.

### FOURMILE FAULT.

A third great strike fault is encountered west of Fourmile Gulch. For 2 miles north of this point it is made evident on the map by the appearance of the red rock in a narrow belt on its west or downthrow side. North of this it extends an unknown distance in the crystalline rock. Its southward continuation runs into the main outcrop of the red rock, south of Fourmile Canyon. The map indicates that at this point a block of red rock is offset to the west. This same block was at first continuous with the isolated fragments to the north, which have subsequently been separated by erosion. The fault has therefore the same general direction and the same relation to the Fountain sandstone as the two faults south of Boulder.

The fault plane itself is not seen, hence the hade is unknown and the depth of the block of sandstone can not be accurately computed. The dip here is but 38°, and the width of the sandstone belt west of the fault is not over 400 feet. If the fault is vertical, the depth of the red-rock block would be but little more than 300 feet. The gorges which cross the fault have cut entirely through the block, and indeed several hundred feet deeper, dividing it into two widely separated parts and isolating both patches from the main outcrop of the Fountain sandstone. Its maximum throw is about 1,100 feet.

### FAULT IN SEC. 25, T. 2 N., R. 71 W.

It is significant of the thrust character of these faults that their directions agree with those of the axes of the échelon folds. This relation is emphasized in the case of a small strike fault 6 miles north of Boulder, in the west half of sec. 25. This fault is on the west slope of the prominent bald hill referred to above (p. 44) as formed of a hard Jurassic sandstone and as marking the end of the syncline where the sandstone is characterized by échelon folding. For perhaps half a mile there is a repetition of less than 150 feet

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of Jurassic strata. This intimate association of fold and fault at once suggests that the two were caused by the same force; and that each supplemented the other in relieving the east-west stress. This would imply a thrust fault, a supposition which is harmonious with all other observations in the district.

### DIP FAULTS IN THE FOOTHILLS.

Dip faults in this area are small. In the next section north of Sixmile Canyon the basal Niobrara shows at least eight dip faults, offsetting the line of outcrop from 10 to 150 feet each—sometimes to the east, sometimes to the west. The belt occupied by the interfault blocks is 300 feet wide. (See fig. 3, p. 44.) The close relation with the folds of the locality leaves little doubt that the two types of deformation are due to the same cause and were produced at the same time. Similar repeated faulting, on a very small scale, also occurs in the Niobrara limestone half a mile south of Gregory Creek. Minute faulting and brecciation at places accompanied the crumpling of the "crinkled" sandstone of the Lykins. It was intense for some distance north and south of Fourmile Gulch.

### POLE CANYON SLIP FAULT.

The apparent dip fault in Pole Canyon is the most prominent feature of this nature and is also of great interest. Viewed casually, the feature especially noticeable is a jog of 400 feet in the Dakota ridge, which on the north side of the stream is small, and disappears altogether within a few hundred feet. This jog, which would seem to be sufficient evidence of a fault, does not appear in any formations older than the Jurassic. Of the younger formations, the Benton and Niobrara show no natural exposures on the south side of the stream. On the north side the Dakota, Benton, Niobrara, and Pierre appear in regular succession. In excavations under the end of the Dakota ridge, on the south side, the Niobrara has been encountered in its normal position, unfaulted. The Pierre and Benton are also unbroken; the upturned edges of the Dakota and Jurassic have slipped forward over the unmoved higher strata. There are two fault planes here—a vertical one in an east-west position and a horizontal one which is considerably higher than the present bed of the adjacent stream. This structure must be called a "fault," though its structural value is quite different from that of a fault, as the word is generally used. For want of a specific designation it is here referred to as a "slip fault." It grades into the landslip, but where characteristically represented, as it is here, its true nature must be taken into account in mapping. It is characteristic of such faults

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that they are (1) superficial and (2) younger than the upturning of the rocks in the foothills.

## HUGGINS PARK.

A feature intermediate between the slip fault and the more ordinary landslip is seen at the middle of sec. 36, at the foot of Flagstaff Hill, west of Boulder. About 300 feet above the plain a bench or terrace a fourth of a mile wide east and west, and of somewhat greater length north and south, is composed of massive beds of the Fountain red rock. Near the front of the bench these rocks are essentially horizontal, but on the west they curve gently upward and become almost vertical. The higher strata from Jurassic to basal Niobrara, inclusive, come up to this bench on the north and on

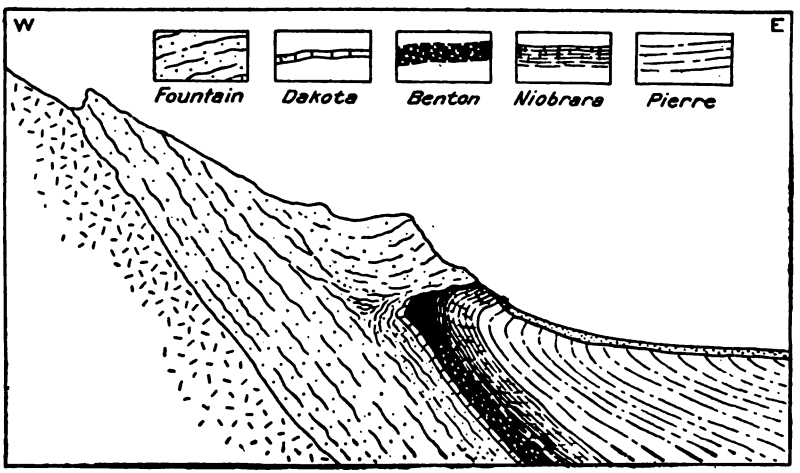



FIG. 4.—Cross section of east slope of Flagstaff Mountain.

the south, and there disappear as if passing beneath the red rock. The bench, known as Huggins Park, is a slide of great dimensions, whose constituent beds are so massive and so unbroken that on the map the red rock is represented as occurring here instead of the higher and younger strata which are covered by the slide. In this case the basal plane, along which slipping has occurred, is in the main a bedding plane, and the phenomenon differs in that respect from the Pole Canyon slip fault.

The recency of this event is shown by a study of the outcrops of the younger strata which were overridden by the red rock in its eastward slipping. The edges of the Dakota, Benton, and Niobrara had been eroded back to a position not differing much from that of the corresponding outcrops which have not been thus covered. When



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the slip occurred these outcropping edges were dragged forward and overturned. Under the eastward-facing scarp of Huggins Park one of these overturned beds of the upper Niobrara has been found in an almost horizontal position[a] (fig. 4, p. 49).

### FOOTHILL OVERTURNS.

Just north of Huggins Park the basal Niobrara and its neighbors are overturned in a manner similar to that just described, though not at the present time covered by the red rock. It is fair to assume that at least a part of these beds were overturned by the original movement and their edges dragged eastward. By a careful examination of the contacts of a dike at the north end of the park, also, Prof. R. D. George has shown clearly that there has been vigorous movement along the planes which bound the dike. The relative motion of the dike rock has been forward (east) with reference to its hanging wall (on its west), and backward with reference to its foot wall. The drawing out of the micas into long streaks plainly indicates this.

As similar overturning is common in the Niobrara of this area, and is sometimes alluded to as "fan structure," implying an origin connected with lateral pressure, the significant features of this occurrence north of Huggins Park are here enumerated. They are as follows: (1) The actual overturn is very superficial, its depth being no greater than the height of the ridge due to the strong stratum of the basal Niobrara above the surface of the neighboring shales, 10 to 20 feet in all. (2) With the exception of this narrow crest there is small difference in dip between the nearly vertical red rock on the west and the slightly overturned Niobrara shales on the east of the basal limestone. (3) The overturn of the limestone increases to the south, where the outcrop swings off to the east toward Huggins Park. (4) The overturn is seen half a mile still farther south, under the red rock in the eastward-facing escarpment of the park.

As pointed out above, this feature resembles fan structure, and it should be so described if interpreted as the result of the profounder processes of mountain making. Recourse to these processes is, however, unnecessary to account for any phenomena within the Niobrara of this area; on the contrary, many of the most pronounced examples of overturn, or fan structure, are clearly the result of mere superficial slipping, aided, no doubt, by frost.

Fan structure occurs most frequently in the Niobrara, but the cause lies in the Benton shale west of the Niobrara outcrop. This shale occupies the steep eastward slope of the Dakota hogback, and its surficial parts may be regarded as having a slow eastward move-

[a] The first recognition of this relation was by Judge Junius Henderson and H. F. Watts. It was first described by Henderson in an article entitled The overturns of the Denver basin: Jour. Geol., vol. 11, 1903, p. 584. Fig. 4, drawn by Watts, is taken from this article.

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ment, due to gravity and frost. This movement has involved many landslips, but it has been chiefly effected by creep. The ocular demonstrations of these processes are patches of hummocky landslip topography and superficial overturning of beds. Overturns in the Niobrara may therefore be regarded as due mainly to the eastward creep of its outcropping edges, which were pushed forward by the Benton from the higher slope. In exceptional cases the outcrops have been dragged eastward by landslips.

It is not quite so apparent that the Dakota should have a steeper dip than the Fountain sandstone from causes similar to the ones here defined. It may be shown, however, that the phenomenon is, at some places, a superficial one. The dip of the block affected by slip faulting in Pole Canyon is 20° steeper than the normal dip of the Dakota in that vicinity. Throughout the area the Dakota hogback is in general a high, narrow ridge, rising much higher above the plains on its east side than above the valley on the west. Against the west side, therefore, there is constant pressure of the Morrison and Lykins shales and sands, whose surface has a general eastward slope and thus a tendency to creep eastward, causing pressure against the Dakota ridge. Under these conditions it is difficult to see how the strata of the latter could entirely withstand the tendency to rotation. Where the strata are thickest and the ridge is broadest, and best supported on the east, the dip is least steepened.

An example in the Fountain sandstone further illustrates the shallowness of the zone in which the dips may be affirmed to agree with those at the surface. West of Boulder, and for a short distance north of Sunshine Canyon, the "Red Beds" are vertical. Going north, the dip decreases with comparative abruptness to less than 60°. The strike continues in a uniform direction, and there is no jog in the outcrop. It follows from this that if these diverse surface dips continue to any great depth the Fountain strata are dropped down sharply, and form a deep east-west trough under the city of Boulder—a supposition which is not supported. There has certainly been, since the middle of the Pierre epoch, a great flattening of the Boulder arch, but it is difficult even to conceive of a structural trough in the Fountain sandstone so profound that its dips should be continuous with the present dips of the crags around Sunshine Canyon. It is far more probable that the steep dips of these exposed crags do not continue far beneath the surface.

### SLIP OF THE LYKINS IN POLE CANYON.

The direct effect of gravity on foothill topography may be seen at various places along the contact of the Lyons sandstones and the Lykins sandy shales. It is well exemplified in sec. 12, just east of

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Green Mountain. (See fig. 5, below.) Here the Lyons sandstone is covered by a long talus slope hundreds of feet high, composed of large blocks derived from the sandstone. The talus slope ends where the Lykins begins. Along this line is a trough, or, more properly, a series of pits, often 20 feet wide and 8 feet deep. Into this irregular trough the lower margin of the talus has fallen. The steeper slope thus made at the foot of the talus has not yet had time to be reduced, and many blocks are in an unstable position. Some have been broken or turned over, and expose fresh surfaces, which contrast with the older weathered or lichen-covered surfaces. Simi-

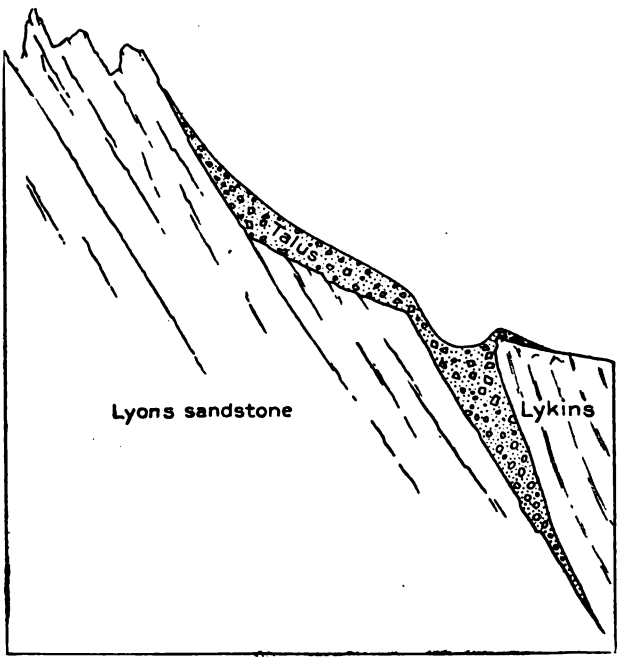



FIG. 5.—Lykins formation in Pole Canyon slipping away from the Lyons sandstone.

lar occurrences are found at various points between Pole and South Boulder canyons.

In explanation of this phenomenon, it is not necessary to assume any other force than gravity. The slope eastward from the contact of the Lyons sandstone and the Lykins is steep and is underlain by shale or sandy shale. At the foot of this steep slope, a fourth of a mile away, a young, deep valley has been cut behind that portion of the Dakota hogback which has been swung forward by slip faulting. (See p. 48.) Similar opportunities for the slipping eastward of the Lykins exist at other points, and are accompanied by the peculiar evidences of slipping described above. The tendency would, of course, be greatly aided by any continuance of the mountain uplift.

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### FAULTS OF THE PLAINS AREA.

The generally horizontal rocks of the plains are broken by faults much longer than those in the foothills. The throws are, however, very much smaller, rarely exceeding 300 feet. Most of the plains faults within this area converge at Marshall and have their chief interest in connection with coal mining. Any description of them must be little more than a repetition of the excellent account given by Eldridge.[a] They have been traced again in the field and plotted with some detail on the large-scale base map used in this survey. All are far from straight, and their courses are necessarily represented in a generalized way. The actual line of a fault can rarely be seen. Commonly its location is fixed only within several hundred feet by outcropping rocks, whose relations indicate a fault somewhere within the limits named. Fragments of crushed and slickensided rock may define the location more narrowly. In two cases faults can be seen in mines. The faults enumerated in Eldridge's "Marshall subsystem" and two of his "North Boulder faults" are here briefly described under the names given by him.

The main or northern fracture of the Marshall subsystem trends southwest along the northern base of Davidson Mesa to its west end, southwest of which its course is more southerly to beyond the middle of sec. 21, where it is lost. Its northeastern extension also runs in the same direction as its southwest end. It passes half a mile west of Burnt Knoll, northeast along the line of Dry Creek, and is lost. The fault plane, where observed by Eldridge, in a mine now abandoned, dips S. 28° E., at an angle of 45°. As the upthrow is on the southeast side, this is a thrust fault. The maximum throw along its middle course is about 350 feet.

The middle fracture branches off from the main fault near the railroad station at Marshall and follows a northeasterly course, though at its southwestern end the trend is more east than north. Its course is curved similar to that of the northern fault, but the curve is less sharp. The line of the fault crosses the highest part of the mesa near its west end, but farther northeast it follows the foot of the mesa. The fault itself can be seen in a cut of the railroad switch, which encircles the mesa at its western base. The maximum stratigraphic throw of this fault is near its eastern end, and amounts to 180 feet. The downthrow is on the south, so that the fault block on the north has been relatively lifted up between its neighbors.

The southern fracture is approximately parallel to the middle one and distant from it one-fourth to one-third of a mile. It follows a gently sinuous course along the south side of the valley, and south

[a] Mon. U. S. Geol. Survey, vol. 27, 1896, pp. 128–136.

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of the Colorado and Southern Railroad, but crosses the valley about the middle of the south side of sec. 15, ascends the mesa to the northeast, and is lost to view in about half a mile. Its southwest end approaches the main or northern fracture near the middle of sec. 21, but here a strong monoclinal fold appears and probably takes the place of the southern fault at its westerly end. The downthrow is on the north and reaches 260 feet. Nearly midway between the middle and southern fractures is another fault of similar direction with downthrow of a few feet on the north.[a]

The block between the middle and southern fractures is cut by the "terminal cross fault," and its west end dropped down about 30 feet. This fault lies a little west of the middle of sec. 15. It trends nearly southeast, but turns more nearly to the south at its southern end, where it seems to cross the southern fracture. It is no doubt the same fault which is encountered in the Gorham mine of the Northern Coal and Coke Company, where the drop on the west side is 10 feet.

The canal fault (so named by Eldridge) is well seen in the deep railroad cut in sec. 13. It runs almost east and west, and has a vertical downthrow on the north of about 50 feet. The massive sandstone on both sides is basal Laramie.

Two of the group of faults appearing on the north side of Boulder Creek lie partly or wholly within the area discussed in this report. No. 1, with upthrow of 180 feet on the east side, brings up the Fox Hills shale in the east halves of secs. 12 and 13 at the eastern edge of the area mapped. The opposing stratum on the west is basal Laramie. No. 2 has 60 feet of upthrow on the east, the opposing strata being Laramie on both sides. All trace of these faults is lost under the alluvium of the valley on the south and also under the surface of Gunbarrel Hill on the north.

## GEOLOGIC HISTORY.

### PRE-FOUNTAIN TOPOGRAPHY.

The geologic history of the Fountain sandstone is considered with especial reference to the topography of the preexisting land surface. The uneven contact between the Archean and Fountain rocks is understood to represent the subaerial topography of Fountain time as modified by shore erosion during gradual submergence beneath the sea. The principles by which the character of the early topography and of the marine denudation is inferred from the present features can not here be discussed in detail.[b] The observations

[a] The writer's attention was called to this small fault by Mr. H. F. Watts.

[b] See the writer, Effect of cliff erosion on form of contact surfaces: Bull. Geol. Soc. Am., vol. 16, pp. 205–214.

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given below, however, point to the conclusion that during submergence the form of the old land surface was much changed by wave erosion.

The Archean-Fountain contact differs from a plane only when broad areas are considered. The undulations of the contact line shown on the map give an exaggerated idea of the unevenness of the Archean surface, but, ignoring the effects of faults, most of the deviations from straightness are due to the irregularities of the present surface.

In the main the proof of the inequalities of the Archean floor is the varying thickness of the red rock. A casual look at the map may be somewhat misleading as to the amount of such variation, for at Boulder, where the band is narrowest, the beds are vertical; toward the north the dip decreases, and where the outcrop is very wide, the dip is but from 7° to 30°. The thickness of the Lyons-Fountain sandstones varies from 500 feet at Boulder to possibly 1,500 feet at Fourmile Canyon and at Bear Canyon, 3 miles south of Boulder. At Lefthand Creek, 3 miles north of Fourmile Canyon, it does not exceed 1,000 feet.

If the eastward tilting due to mountain-making forces were undone and the red rock removed, the exposed Archean surface would show only very smooth, broad undulations. In this area the slopes would not be less than 3 miles long, would have a grade, except at one place, not exceeding 150 feet to the mile, and would be entirely unbroken by valleys. The one exceptional feature of the relief would be a hill, or east-west ridge, at Boulder, rising possibly 1,000 feet above the valleys north and south of it, but having a base 6 miles wide and perfectly smooth slopes. This hill or ridge, however, marks a well-known line of weakness, along which there has been frequent uplifting; it does not, therefore, represent the relief of the floor upon which the Fountain sandstone was laid; it was more probably being elevated during the deposition of the latter, or, rather, it was subsiding less rapidly than the areas north and south. (Compare p. 64.)

The Archean rocks below the Fountain are unweathered. Those which are in immediate contact with the red rock do not differ in this respect from those which occur at a greater distance back in the mountains. In like manner, the felspathic constituents of the stratified rocks are essentially unchanged. The sediments also contain many unweathered rock fragments. The material composing much of the red rock is not unlike the disintegrated granite which now covers many of the steepest hillsides, with this exception, that it has been to some small extent transported by water. Nevertheless, these sediments are in the main but little waterworn and poorly assorted. They are such as should be found near a land which is being actively

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eroded by streams as well as by waves—that is, where erosion is relatively active as compared with weathering; the more arid the climate the less active need erosion be in order to yield such waste. Such sediments belong to a shore where trituration is not prolonged, and where the bottom subsides so rapidly that the particles are carried downward into quiet water before they have been rounded or broken up.

The above features of form and material suggest that the configuration of the present contact is the result of a considerable change in the topography of the old land. The absence of smaller irregularities on the broad swells that slope 150 feet to the mile and an unweathered rock bed would not both characterize an area subjected to subaerial erosion. If the former land surface was a peneplain its deeply weathered surface could not have supplied the large proportion of feldspar fragments in the red rock, and its slowly flowing streams could not have transported them from the higher land on the west. On the other hand if the surface had its present relief its long slopes would have been cut into sharp hills and valleys. The invading sea, therefore, must have shaved from the surface enough material to obliterate all the relief except the major features, which have been left in a very generalized form.

### SHORE EROSION DURING SUBSIDENCE.

The form of the shore line of an advancing sea is indicative of the form of the sea bottom near the shore. This is apparent from the fact that the shore line at any stage of subsidence is the highest contour of the sea bottom and is similar to the other contours, each of which was, in its turn, the shore line. When the submerged surface, therefore, is a plane, whose contour lines are straight, the shifting shore line is known to have been without bays. When the sea bottom is undulating, the shore line of the advancing sea was characterized by bays and headlands.

During the invasion of the Fountain sea, therefore, the shore line was not straight (since the surface of denudation is not a plane), but there has been found no trace of bay heads where filling was in progress. The universal freshness of the underlying granite is evidence that cliff cutting occurred everywhere. The bays that existed did not extend so far inland as to preclude erosion at their heads. While this universal cliff cutting was taking place the surface rocks were being removed from both hills and valleys, though the erosion was greater on the hills than in the valleys. Between headlands 6 or 8 miles apart the water would have been possibly 500 feet deep. These dimensions, which follow from measurements given above, are perfectly consistent with the assumption that the bays were so wide open as to allow wave erosion at their very heads.

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The supposition is a long way within the possibilities of shore erosion.

From the above-stated relation of the shore line to the contours of a submerged surface it follows that if a retreating shore line is a sinuous cliff the sea bottom will have a fluted surface. There will be ridges along the lines of retreat of the headlands and furrows where the bay heads receded. If there is suitable offshore slope and rate of subsidence, even the coarse waste may be laid down in beds, which are continuous over these ridges, instead of abutting against them. All these conditions occur along the lower contact of the Fountain sandstone. Fine flow-and-plunge structure is seen where it should be expected—that is, in the thickest part of the formation or within the bays of the Fountain sea.

All the undulations of the Archean floor might be due to gentle crustal folding during Fountain time. This hypothesis also would provide for the continuity of the "Red Beds" over the eminences. It would make unnecessary the assumption that hills stood out as promontories in the advancing sea and that the shore line was crenulated. It does not, however, account so well for the general cross-bedding, and for the flow-and-plunge structure that so plainly characterizes the places which, on account of the greater thickness of the "Red Beds," are regarded as bays. Except in the vicinity of Boulder there is also a lack of collateral evidence of such crustal deformation. The hypothesis of warping during sedimentation might be used to support the theory of a pre-Fountain peneplain, but it has already been pointed out that the character of the Fountain sediments does not admit of the assumption that they were derived from a peneplain. The Boulder arch itself was probably slowly bulging upward while the "Red Beds" were being deposited. The evidence on this point is given under the discussion of the next higher formation. (See p. 61.)

## DEPOSITION OF FOUNTAIN FORMATION.

Generally speaking, the local thinning of the red rock is due to thinning of all the beds rather than to a disappearance of a part of them. Except in the vicinity of Boulder the topmost strata of the formation can be traced continuously from point to point along the line of towering crags, which form the most conspicuous feature of the foothills. The Lyons sandstone shows the same continuity at a higher horizon, and the strata at the base of the red rock are almost or quite as continuous as those at the top. If the contact is followed from canyon to canyon over the intervening spurs, the basal ledge of the red rock may frequently be seen for a mile or more. In almost all such cases the continuity of the stratum at the base is noticeable, although this is not quite universal, as there seem to be

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a few places where the beds at the base abut against a low rise in the granite surface. At such places the contact appears to shift to successively higher beds of the red rock.

### DEPOSITION OF LYONS SANDSTONE.

The change which brought about the deposition of the Lyons sandstone was comparatively abrupt. Only a short time after the deposition of rough arkose, the sediments were composed of thoroughly assorted clean-washed quartz sand. The details of structure also changed to a neat cross lamination, producing flags of a uniform thickness and large area. Most of these flags which are now exposed dip east at a smaller angle than the true bedding; that is to say,

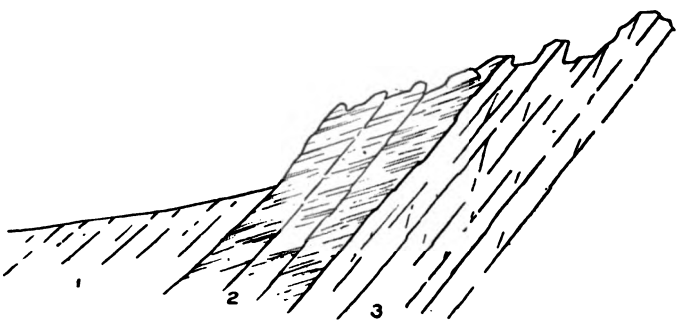



FIG. 6.—Position of cross-bedding of the Lyons sandstone. 1. Lykins formation. 2. Lyons sandstone. 3. Fountain sandstone.

if the true beds were again horizontal the cross-bedding would dip west, or toward the old shore. (See fig. 6.)

### BAYS AND BARS.

The nature and peculiar bedding of these sediments indicate that the shore line was indented on the west by a bay, and that this bay was spanned by a bar of clean sand—the formation known as the Lyons sandstone. Most of the sandstone now exposed was deposited on the landward side of the bar and dips toward the land. The area here discussed embraces parts of two such bays, separated by a salient point between Boulder and Gregory creeks. (See fig. 7, p. 60.) In front of this headland the peculiar sediments ascribed to bar building are absent.

Not only are the bar sands absent from this locality, but the headland seems to have been eroded and to have furnished a part of the material for the bars. It can not be stated beyond doubt that there was such erosion, because, at the place concerned, the upper beds of the red rock are poorly exposed. It is certain that just west of

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Boulder the red rock is much thinner than it is a short distance to the north or south. From appearances it is probable that this decrease in the thickness of the formation is due in part at least to thinning of the individual beds, but it is not plain that the whole difference can be thus accounted for. In so far as the upper beds fail to cross the arch,[a] it is most consistent with the physical history to assume that they were eroded from the headland which, without doubt, projected at this point when the bars of the Lyons sandstone were being deposited. Cliff erosion on the salient would certainly be expected from the relative position of the headland and bar.

These bays could not have resulted from the continued submergence of an uneven land surface. The headland at Boulder was plainly due to warping resulting from north-south stress. It corresponded in position to the Boulder arch, which has been subjected to repeated upward warping. As the sediments became thinner at this place and as a headland appeared immediately after their deposition, while sedimentation continued to the north and south, the cause of all these phenomena was no doubt crustal deformation.

The conclusion that the Lyons sandstone is the sediment of bars rests finally upon the position of its cross lamination, which in general dips toward the shore. This necessitates either the above-stated hypothesis of bars or that there was land farther east from which sediments were derived. The supposition that there was land farther east is entirely without support. The hypothesis that the sands were laid down in the form of bars is supported by the nature of the sands and by their absence at the most probable headlands, from which, in part, the shore drift should have been derived.

It is to be remarked that the dip of the cross-bedding at Gregory and Boulder canyons, where the formation abuts against the supposed headland, is away from the mountains. The Lyons sandstones exposed at Boulder and Gregory canyons are in immediate contact with the old headland, and therefore represent the seaward side of the bars. From the nature of the contact of a bar with the salient from which it springs, it is the seaward front and not the inside or landward slope of the bar that is tangent to the land. (See fig. 7, p. 60.) Whatever cross-bedding existed on this seaward front must, of necessity, have dipped seaward. Therefore the relative eastward dip of the cross-bedding at these places is in exact accord with the theory of the deposition of these sands in the form of bars.

The supposition that two bays were separated by a salient between Boulder and Gregory creeks rests upon (1) the absence of bar sediments at that point, (2) the probable erosion of the topmost red

[a] See Eldridge, G. H., Geology of the Denver basin: Mon. U. S. Geol. Survey, vol. 27, 1896, p. 110.

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rock, (3) the eastward dip of the cross-bedding of the beach sands nearest to this point.

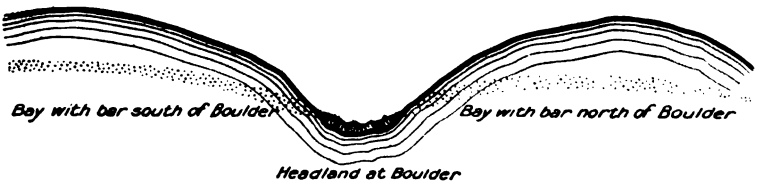



FIG. 7.—Shore line during the deposition of the Lyons sandstone.

From the above reasoning it follows that the Lyons sandstone should be intermittent in its distribution alongshore after the manner of bars. This is true. They should also form a relatively narrow reef-like zone, and, if followed outward from the old land, the direction of dip of the cross lamination should be reversed. Along this line no direct evidence is at hand.

### MIGRATION OF BARS.

A bar extending across a bay retreats landward with the recession of the cliff from which it springs. This retreat is accompanied (1) by progressive deposition on the landward side of a series of layers which dip toward the land, and (2) by erosion on the seaward side, which results in the removal of the upper part of layers previously deposited.[a] (See fig. 8.) The first effect is exemplified here in the prevailing dip. The second is beautifully shown wherever there is a good contact between the Lyons sandstone and the next higher formation. The bottom of the Lykins is occasionally exposed as a clearly defined surface against which the clean-cut flags abut at an angle which may reach 36°. (See fig. 6, p. 58.)

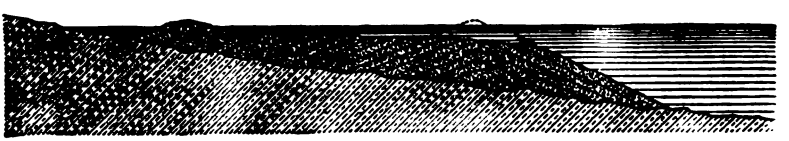


FIG. 8.—Section of a linear embankment retreating landward. The dotted line shows the original position of the crest. (After Gilbert.)

This process of building bars of clean-washed sand, which are shifted gradually landward and truncated, implies a considerable stability of the land with reference to the sea level, though it is not prevented by moderate sinking. In the epoch here considered, not only the well-assorted, clean-washed, creamy sands, but also the shaly sands which follow, indicate quiet conditions and freedom from crustal deformation.

[a] Compare Gilbert, G. K., Lake Bonneville: Mon. U. S. Geol. Survey, vol. 1, 1890, p. 53. The conditions here described are discussed by Gilbert, as exemplified in the mole inclosing Toronto Harbor. Fig. 8 is taken from this discussion, p. 56.

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### LYKINS SEDIMENTATION.

While the bars of Lyons sands were being truncated sediments could not be deposited on the truncated base unless they were coarser than the sand which had been removed. Later, however, this surface subsided to such a depth that it was buried by a sandy and highly ferruginous mud.

The deposition of the other sediments of the Lykins formation required similar depth, and during this time there was nothing peculiar in the shore conditions. Probably at this time while the sea bottom was depressed so that mud was deposited in places from which sand had been removed, the relief of the land was reduced, and thus the supply of coarse sediment was checked. During much of Lykins time the sea was so deep that ripple marking and cross-bedding did not take place, but toward the close both are apparent.

### LYKINS WARPING.

At Twomile Canyon the cross-bedding near the top of the series again indicates deposition on the landward side of a bar. It may be inferred from this that headlands were again being eroded, and this assumption is borne out by the nature of the sediments, which are coarser near the top. The headlands were probably caused in part by a gentle warping, which harmonizes with indications of crustal movement at the close of the Lykins, which may have caused a slight unconformity between the rocks of this epoch and those of the Morrison. The brown sandstone at the top of the Lykins is not of uniform thickness. (See p. 25.) The exceptional abruptness, also, with which at many places the highly ocherous rocks give place to the gray above, at least raises the question whether there might not have been a transitional stage whose record is lost. As pointed out in the description of the stratigraphy, such beds, transitional in color and texture, appear in a number of places.

*Uplift of the Boulder arch.*—While clear and definite indications of a general unconformity at the top of the Lykins are wanting, there is decisive evidence that the Boulder arch was uplifted and eroded. The "crinkled" sandstone approaches to within a few hundred feet of the south side of Gregory Canyon, maintaining about its usual distance above the Lyons. The same conditions are found on the north side of Boulder Creek, but for more than half a mile north of Gregory there is no trace whatever of the Lykins. The uplift of the fold north of Gregory Creek was almost equal to the combined thicknesses of the Lykins and the Morrison. The former is normally from 600 to 800 feet thick and the latter is not less than 150 feet. Only the topmost beds of the Morrison probably covered the arch and are concealed beneath the talus of red rock.

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## MORRISON SEDIMENTATION.

The Jurassic in this vicinity is represented by but one formation, the Morrison. The physical history of the period is not well indicated within this area. Fossils have not been found here, but those collected at other places show that the water of the Morrison sea was fresh. On the north and south, therefore, the ocean was shut out by land barriers extending east from the mountains to other land at an unknown distance.[a] At first the Boulder arch stood less than 100 feet above the water, and its height above the sea was gradually reduced by subsidence or by a change of the lake level. The arch was probably covered by the upper beds of the Morrison.

At a distance from the vicinity of the Boulder arch, the clays at the summit of the Jurassic have a nearly but not altogether constant thickness. If present at all between Gregory and Boulder canyons, they are very thin. Erosion is plainly indicated. The fresh-water lake gave way to land. Paleontologic evidence taken from broader areas indicates that this area was land through the whole of Lower Cretaceous time. The relief of this land surface was low. This is inferred not only from the fact that no valleys appear in its present buried surface, but also from the nature of the sediments when it was again submerged.

## DAKOTA SEDIMENTATION.

At the beginning of Upper Cretaceous time the sea again covered this region. The first bed of sediments laid down contains much sand, but consists largely of very resistant and generally well-rounded pebbles of quartz, quartzite, jasper, and chert. The selection and separation of such materials from the waste of the previous land surface are consistent with low relief and deep weathering.

These facts are best explained by assuming that these residual pebbles of very resistant minerals were embedded in the surficial deposits of the submerging land. The soil sheet was worked over and assorted by wave action and these large pebbles deposited near shore. An unknown quantity of such deposits, brought down by streams from the land to the west, is doubtless mingled with the material derived from the submerging mantle rock. The finer and much more abundant products of decomposition were necessarily deposited farther seaward. According to this explanation this conglomerate is a shore phase of the lowest Dakota beds.

Mingled with the hard pebbles are occasional fragments of rocks, such as limestone, clay, and feldspathic rocks, that would readily yield to weathering and wear. These may have come in part from

[a] Emmons (op. cit., p. 24) suggests that the Morrison lake may have extended from near the northern boundary of Colorado to the latitude of the Raton Hills.

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cliffs that were cut from low hills of the old land surface. They also suggest what they alone would not be sufficient to prove, namely, that the oncoming of the sea was accompanied by some warping and steepening of the land; but of this there is other evidence, as follows:

Before the close of the Jurassic the Boulder arch was covered by sediments, which were not entirely eroded away during the succeeding land epoch, showing that the land must have been very near the sea level. The absence of the lowest Dakota near Boulder, however, shows that just before the Dakota sediments were laid down elsewhere there was a differential subsidence amounting to a renewal of deformation along the old line.

### BENTON SEDIMENTATION AND UPLIFT.

As a result of deepening of the sea, decrease in the relief of the land, and gradual removal of the shore, the Dakota sands were followed by the Benton shales, not suddenly, but after some alternation of sediments. The arching was again strongly renewed, this time between Sunshine and Boulder canyons. Erosion cut away the entire Dakota, but there is nothing to show whether the Jurassic was further wasted. The uplift remained above water until very near the close of the Benton epoch. Only the very latest beds of the Benton are continuous over it. The amount of uplifting at this time was therefore approximately equal to the combined thickness of the Dakota and Benton. The average thickness of these formations north and south of Boulder is not less than 700 feet.

### NIOBRARA SEDIMENTATION.

The deposition of the Niobrara was not accompanied by noteworthy physical conditions, except those attributable to diminishing sediment, removal of shore, or deepening water. There is no evidence in this area of any disturbance at its close.

### PIERRE SEDIMENTATION AND FOLDING.

As a single mass of shale, the Pierre is extraordinary on account of its great extent and thickness. A discussion of the factors adequate to produce these results would not be possible from observations in this small area. It is safe to assume that during Pierre time there was a steadily sinking sea bottom and a steadily rising land that had a relief sufficiently low to allow thorough decomposition. The sinking area on the east and the rising area on the west were necessarily separated by a monoclinal fold of increasing height. It is highly probable that this fold lay along the line of the present foothill belt and that although its dip was more gentle than that of the present great monocline it determined the line along which the forces

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of mountain making later gave form to the steep monocline which now follows the eastern border of the Archean belt.

The record of changes on the Boulder arch continues legible during a considerable fraction of Pierre time. The arch continued to rise relatively—that is, it sank less rapidly than the adjacent areas. This is shown by the position of the Hygiene sandstone. At Boulder this stratum is separated from the Niobrara by barely 1,000 feet of Pierre shale. Five miles farther north the same shales are 3,000 feet thick, showing a relative rise of the Boulder arch amounting to 2,000 feet during the first half of the Pierre epoch. The record of the latter half of Pierre time is not clear, because there are not enough outcrops to allow satisfactory determinations of thickness over the Boulder arch. The shale-making conditions were not uniform throughout the epoch. The deposit of so thick and continuous a sandy stratum as the Hygiene sandstone probably indicates a temporary dominance of the uplifting forces over subsidence.

### FOX HILLS SEDIMENTATION AND LARAMIE UPLIFT.

There were no noteworthy physical changes at the beginning of or during the Fox Hills epoch, except variations similar to those which occasioned the sandy layers in the Pierre. The Laramie indicates a general uplift, both by the coarser character of its sediments and by its beds of coal.

### SUMMARY OF HISTORY OF THE BOULDER ARCH.

With the exception of the growing monocline which separated the sinking sea bottom on the east from the rising land on the west, the Boulder arch is the index of all the crustal deformation definitely recognized as occurring in this area before the Rocky Mountains were formed. It is noteworthy that the forces which caused it acted in a north-south direction. In the later deformations east-west forces were completely dominant.

From the evidence given above, the successive rises of this east-west anticline may be summarized as follows: During the Boulder and Lyons epochs there was a rise which may have reached the maximum limit of 1,000 feet. (See p. 55.) The axis of this movement was south of Boulder Creek. At the close of the Lykins there was a further elevation, approximating 850 feet. (See p. 61.) In the interval between Jurassic and Dakota there was a relative elevation whose minimum may be placed at 25 feet. The uplift at this time may have been broad, extending from south of Gregory Creek to a mile north of Sunshine Canyon. At the close of the Dakota the minimum uplift was 700 feet along an axis between Sunshine and Boulder creeks. In the first half of the Pierre epoch the further rise amounted to 2,000 feet.

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Maxima are given in some cases, and minima in others, but the sum of all the above amounts, which is 4,575 feet, may be taken as an approximation to the total elevation of this anticline.

An examination of the geologic map shows that there has been a great depression of the Boulder arch since the formation of the Hygiene sandstone. If the strata of the foothills and the plains were now deprived of their eastward dip, the upper beds would show a pronounced east-west syncline on the site of the former anticline. Even in the lower beds little of the former east-west anticline remains. Since the Hygiene sandstone is the youngest formation that gives evidence concerning the age of Boulder arch, the date of this flattening can not be fixed within narrow limits. A similar arch, stretching eastward from Golden, about 17 miles to the south, can be studied in more detail, because of the presence of younger strata. Emmons[a] and Eldridge[b] held that the flattening of the Golden arch may have occurred in Denver time, and perhaps was due in part to the extravasation of basalt along the line of the old anticline. The two arches had almost the same history, and the sites of both are marked by volcanic extrusions. Cross assigns the eruptions to the same epoch. Whatever causal relation exists between the extrusions near Golden and the flattening of the Golden arch may also be assumed to exist between the Valmont dike and the depression of the Boulder arch.

## POST-LARAMIE HISTORY.

Post-Laramie history is recorded in the deformations incident to mountain making and in the forms due to erosion. The time of most of the events can not be accurately determined by local evidences.

Topographic features due to erosion are presumably in the main Quaternary. They indicate continuous degradation that has resulted in a series of river terraces. With the exception of the small fragments of the loess sheet (see p. 35) and a few isolated alluvial fans, there are no fluviatile deposits except those left by degrading streams. There is no broad sheet, such as that of the High Plains,[c] implying an epoch of stream aggradation. Everywhere the stratified rocks of this margin of the plains have been neatly pared off by meandering streams. The sheets of gravel which cover the planed surfaces are such as down-cutting streams should be expected to leave.

[a] Mon. U. S. Geol. Survey, vol. 27, p. 50.

[b] Id., p. 100.

[c] Johnson, W. D., The High Plains and their utilization: Twenty-first Ann. Rept. U. S. Geol. Survey, 1901, pp. 651–656.



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No features in this area require for their formation streams larger than the present ones. The present Boulder Creek is a degrading stream, with moderate meanders and a broad flood plain sloping toward the stream. Where it reaches the bluffs which front its terraces the river is cutting into the bed rock and planing off a surface on a level with the bottom of its channel. On this planed surface it is depositing a sheet of heavy gravel and finer alluvium, similar both in character and thickness to the sheets which everywhere cover the mesas and other terraces. (For a more explicit comparison see p. 14.) That the streams which caused the present plains topography were degrading their channels is plainly shown by two facts: (1) The débris sheets have a uniformly limited thickness, and (2) the terraces always slope toward the streams to which they were flood plains. This continuity in the cutting by the streams gives to the erosional history of the district a unity which makes subdivision impracticable.

This uniformity of erosional history near the foot of the mountains is in contrast with the more complex history of the plains farther east,[a] where the denuding processes have plainly been interrupted by aggradation one or more times. The obvious inference is that the entire recorded erosional history of this narrow belt must be matched with the last epoch recorded on the plains, which is one of stream degradations.[b]

It is entirely natural that when the character of streams is changed, whether from aggrading to degrading, or the reverse, the belt nearest the mountains should be the first to suffer complete obliteration of the records of former conditions. The rivers may recently have acquired increased cutting power by an uplift on the west that increased their grade, or by an increase of rainfall, or, as Johnson suggests, by a mere cooling of the climate, which would decrease evaporation. In any case the upper course must first be cut down and in this the records of former aggradation will first be erased. If the change of stream habit be the reverse, the prompt burial of features near the mountains is equally well understood. If the climate is moderately arid, as in the area under consideration, there is an additional reason for the prompt erasure of aggradation records near the mountains, as running water is more abundant there, many streams actually losing volume as they proceed.

[a] Johnson, W. D., op. cit., p. 628; also Emmons, S. F., op. cit., p. 255.

[b] As to the geologic data of this epoch Johnson says (op. cit., p. 630): "The beginning of the final and present degradation, during which the smoothness of the Great Plains has been in large part destroyed and their surface lowered, with the exception of the sod-covered plateaus of the central zone, doubtless dates from the opening of that period of climatic oscillations in the Pleistocene which, in the Great Basin region of Utah and Nevada, gave rise to repeated floodings of large areas and the creation of lakes."

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## ECONOMIC GEOLOGY.

### WATER.

#### SURFACE ZONE.

Ground water in the area under consideration is found at moderate depths. Over the well-drained parts of the plains it is commonly encountered at depths of from 10 to 20 feet. Since the bed rock is in large part relatively impervious shale, the slope of the ground-water surface is very similar to the slope of the ground. One bluff 40 feet high is quite dry at the base, but on the terrace above, less than 200 feet from the bluff, water is found at a depth of 12 feet. The surface shales are everywhere more permeable than the unweathered rock below, and the movement of water in them is freer than at greater depths. In drilling oil wells, therefore, it is found necessary to case off this surface water.

#### DEEPER ZONE.

Below this superficial zone, which is 25 to 50 feet thick, the shale is so dense and the consequent movement of the water so slow that wells are spoken of as "dry." At irregular intervals within the shales, as deep as the formation has been explored in drilling for oil, are sandier beds of limited lateral extent. In these the movement of the water is more rapid, and after drilling through them it is sometimes necessary to case off the water from these deeper sources. When the character of the water is suitable, these beds might afford supplies for deep wells, but the water is not infrequently slightly saline, and it may be a brine. Flowing wells are not obtained from these sources in the Pierre shales, nor are they expected, on account of the limited lateral extent of the sands and their close texture where unweathered.

#### FLOWING WELLS.

South of Burnt Knoll, about 6 miles southeast of Boulder, a faint flow of water was obtained from the Laramie at a depth of 80 feet. A similar flow was obtained at Lafayette, 11 miles east of the foothills, at various depths between 400 and 700 feet. It was encountered while drilling for oil.

At the north end of the field the Stuart well, drilled for oil, encountered abundant water in the Morrison formation. At last accounts (April, 1904) the well was still flowing. It is located on the Pierre shales, one-half mile east of the Dakota outcrop (SW. $\frac{1}{4}$ of sec. 5, T. 2 N., R. 70 W.). The dip of the beds at the surface is here 26°. The succession of strata passed through leaves no doubt

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that the Morrison was encountered at a depth of 1,336 feet. If all the beds passed through dip at an angle of 26° and have the thickness given above, under the heading "Stratigraphy" (pp. 20 et seq.), the Morrison should have been found at a somewhat greater depth than 1,336 feet. Probably at a short distance below the surface the dip is less than at the surface, where it has been steepened by the process described above as tending to produce a fan structure. The water is from a horizon about 60 feet below the top of the Morrison; it is therefore from one of the upper beds, probably from the "Saurian" sandstone. This supposition is supported by the fact that the water comes from yellow sand. Presumably the lower and larger Morrison sandstones, and especially the basal stratum, would yield water still more copiously. This assumption is supported by observations on the small stream flowing east over the Lykins and Morrison outcrops in Lykins Canyon. The channel when examined was dry as far as the outcrop of the Morrison. At this point water appeared within a few yards and there was a flowing stream. No well, however, has reached these lower beds, the Stuart being the only one which is known to have entered the Dakota. The high dip of the strata makes it impracticable to obtain water from even the best beds of the Morrison except within a narrow strip east of the foothills.

### WATER IN THE DAKOTA.

Water was obtained in the Stuart well from the Dakota, but not in amount to be compared with that from the Morrison. The relations of the Dakota are not favorable to any great water supply for northern Colorado. The hardness of the formation causes it to outcrop in a single rocky ridge, which quickly sheds the precipitation and is unfavorable to percolation. True, the outcrop is crossed by streams flowing from the mountains, but even this intake must yield a small supply on account of its extremely restricted area. Moreover, the Dakota sandstone is practically sealed below by relatively impervious shales and clays, and therefore can not receive much of the water that penetrates the lower strata which outcrop west of the Dakota hogback. If the Dakota of northern Colorado be compared in these various respects with other well-known water-bearing strata—for example, the Potsdam of central Wisconsin, or even the Dakota sandstone of the Black Hills—its area of intake will be seen to be very small and topographically unfavorable to percolation. The slow inflow into the Stuart well from this formation also indicates that it is denser than the sandstones of the Morrison. The Morrison sandstones, though much thinner than the Dakota, outcrop in a valley, or on the western slope of the great ridge of which the Dakota forms the crest. In either case their

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edges are generally covered with a sheet of loose waste, favorable to percolation.

## BUILDING STONE.

In the matter of building stone the area here described is typical of a much longer stretch of the foothill belt of which it forms a part. Most of the formations yield valuable economic products, the building stone coming mainly from strata not younger than Jurassic.

### GRANITE.

Within the area mapped granite has not yet been quarried or even studied with reference to its use as building stone. Apparently, however, the area may furnish granite for architectural purposes of suitable grain, color, strength, and size of block.

### THE RED ROCK.

The great mass of the Fountain red rock is not appropriate to building purposes. Locally, however, there are, near its summit, beds of the finest quality of structural stone. One-fourth mile north of Fourmile Canyon a quarry has recently been opened at this horizon to supply material for the new Episcopal Church at Boulder. In contrast with the prevailing arkose character of the Fountain, these exceptional beds are even-grained, quartz sands, containing only here and there minute grains of feldspar. Biotite scales are rather plentiful, and are arranged parallel to the bedding, so that transverse faces show only very minute black lines, which are not sufficiently prominent to indicate the position of the bedding except by very close examination. The stone is of a light pink color, which runs uniform so far as the quarry referred to has been worked. Except in the biotite, all the contained iron is supposably in the peroxide form, and the stone contains nothing to cause a stain upon exposure to the weather. The stone is massive and must be dressed on all sides of the block. Blocks which dress 2 or 3 cubic feet are frequent. The strength has not been tested, but there is no doubt an ample margin beyond the needs for all ordinary building purposes.

### LYONS SANDSTONE.

This is by far the most abundant rock of economic importance within the area described, and probably within the foothill belt north of Denver. The name "creamy" sandstone, which is often applied to it, is unfortunate, for it is distinctly pink. It varies somewhat in

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color, however, and at one extreme it may reach an almost creamy tint, while at the other it may be red. Still, the great mass is so uniform that stone from many quarries might easily be used in one building. The standard color of this stone has more of the creamy and less of the vermilion tint than that of the rock quarried from the Fountain sandstone. It does not develop any discoloration in the wall.

In composition the stone is of the purest even-grained quartz sand, its siliceous cement deriving its color from ferric iron. The cement is so abundant as to make the stone quartzitic, and it is known in the trade as a crystalline sandstone.

The distinguishing feature of the structure of this stone is its delicate lamination and perfect partings in the quarry. Fifty laminations to the inch may sometimes be readily distinguished, but at a distance of a few feet the lines are invisible and the stone has a uniform tint. Occasional stronger lines may make the lamination more prominent.

In the quarry the stone parts perfectly into thicknesses varying from a fraction of an inch to more than a foot. Flagstones of convenient thickness and having as much as 60 or even 80 square feet of surface may be obtained. The flagstone industry has its center at Lyons, about 3 miles north of this area. Near Boulder the thickness of the beds is generally greater, and the stone is commonly quarried for building. The blocks for this purpose may be as thick as 15 inches, but the average is probably not above 8 inches. As the bedding planes are perfectly smooth and parallel, the blocks require dressing on four sides only. Both the convenience and the strength of this stone cause its general use in foundations in the near-by towns and cities. It is also used for the superstructure in some large and handsome buildings. The stone is likewise in common use for sills and curbings. As pointed out on page 24, the bedding planes observed in nearly all quarries of the Lyons sandstone are those of the cross-bedding, having had a dip toward the shore on the west when deposited.

The amount of this stone in northern Colorado is enormous. If its workable thickness in this area averages 50 feet and if quarries be worked 100 feet down the dip of the stratum, each linear mile of the foothill belt would yield 1,000,000 cubic yards of stone.

### RED SANDSTONE OF THE LYKINS.

Stone from this series of beds is not quarried in this area. At a few places the Lykins yields a very fine-grained and close-textured red sandstone, easily worked and readily obtained in large blocks.

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The same stone occurs abundantly within this area, but, whether from the repeated warping of the Boulder arch or from the diagonal compression resulting in the échelon folds, it is too much fractured to be obtained in large blocks. This is the case at each of the few places where it has been prospected.

### WHITE SANDSTONE OF THE JURASSIC.

The chief quarry opened in the lowest Morrison sandstone stratum is known by the name of Doctor Bond. The product of this quarry is a slightly calcareous sandstone of moderate strength, of a gray color, inclining toward yellow rather than blue, and having no lamination or subordinate bedding planes within a 10-foot stratum. It is not always free from iron stains, which may appear in the quarry or may develop after building into the wall. Large dimension stones are readily taken out and easily worked. The bed in which this one quarry is opened has a fairly uniform thickness and character for many miles. It is probable that in the future this stone will be quarried much more extensively.

### BUILDING STONES FROM THE CRETACEOUS.

But little stone is quarried from strata younger than Jurassic. The Dakota is very strong, but difficult to work, the blocks generally requiring dressing on all sides. Within this area it need scarcely be taken into account, as it is accompanied by other formations containing such vast stores of more desirable material.

The massive summit sandstone of the Fox Hills is quarried in considerable quantity farther north. It is but little exposed within this area, and where found it is commonly too weak for structural purposes. Beyond the eastern border of the area it is not improbable that this stone will be found locally of fair quality.

The white sandstone of the Laramie can scarcely be called a commercial product. It is present in great quantities and easily taken out and worked in blocks of large dimensions, and a few houses have been built of it. Its strength, however, is small, and it is much stained with iron.

### GRINDSTONE.

The white sandstone at the base of the Morrison, which is used for building purposes as described above, is locally used for grindstone and enjoys considerable favor. About a mile north of Altona a quarry, known as the "Grindstone quarry," has been opened by Peter Haldi, of Altona. The few grindstones from this source which

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are in regular use have been dressed by hand. To all appearances they are doing their work in a highly satisfactory manner. The grain is fairly sharp, the cement is very slightly calcareous, and the stone is easily dressed. Several much-used surfaces seemed to be clogged with the muddy products of the abrasion of the stone itself, but the users maintain that such an occurrence is the result of improper use. The crude methods of quarrying have produced rather small and ill-shaped blocks, but, judging from the same stratum where quarried for building purposes, this does not indicate any fault in the stone itself. Suitable shapes and sizes can no doubt be easily obtained.

## LIME.

The production of quicklime is carried on to a limited extent. The stone used is mainly from the basal stratum of the Niobrara. At various places also the limestone lenses of the "crinkled" sandstone in the Lykins have been utilized; occasionally also the beds in the Morrison. The limestone of the Niobrara is highly magnesian [a] and very dense. On account of its density it does not calcine very readily and the large percentage of magnesia makes a "cool" lime.

## CLAYS.

### OPPORTUNITIES FOR THE BRICK INDUSTRY.

The brick industry at Boulder is already large and there is no necessary limit to its expansion, except the size of the market, the raw material being presumably inexhaustible. It appears, however, that the Pierre shale, which is the chief resource for red brick, is not entirely uniform in its brick-making properties. Yards within the limits of Boulder produce bricks differing in shrinkage, density, and strength. As the surficial aspect of the Pierre shales is highly uniform for long distances, it is very probable that laboratory tests will come into general use in the locating of yards as the industry expands.

Red brick must always constitute the chief product of the clay industry. Three plants, each with a capacity of 20,000 bricks a day, are operating steadily at substantially full capacity. These are all using the Pierre shale and are practically within the city of Boulder. The Benton has not been used. At present all the pits are on mesa edges, the mesa in each case being from 30 to 50 feet higher than the adjacent lowland. While such a situation may be desirable from

[a] An analysis of Niobrara limestone is given by Eldridge, op. cit., p. 67. It shows 18.03 per cent MgO.

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the standpoint of moisture conditions, it is mainly a matter of convenience, and must not be understood to be necessary. There is nothing to bar from future use any part of the shales of the Pierre belt as shown on the map.

### SHALE SUPPLY.

At each of the three pits the shale is covered with the rough mesa gravel, which at one place has a thickness of 15 feet, and which is removed. Where the mesa gravel is almost absent, the clay resulting from decomposition of the shale may be as thick as 2½ feet, but this is of no significance in the manufacture of brick. Where the mesa gravels are thick, the clay is wanting. The shale is almost free from lime, though some highly calcareous nodules occur, sometimes containing fossils. Occasionally, also, a thin plate of shale is dark and hard with impregnated iron, but the quantity of such is almost negligible.

If the shale is not reduced to clay, it is not to be understood that it has been entirely unaffected by weathering. Its bedding remains perfect and it is apparently unweathered, but where excavation is deep the color is always observed to change from a greenish drab above to something darker (commonly called "black") below. Throughout the belt underlain by the Pierre, though the normal color varies, the surficial zone shows almost the same greenish-drab color. This ends abruptly at a depth of 30 feet, more or less. In the black shale (or "slate") below lamination is less apparent, and large masses break with a conchoidal fracture. Naturally the concretions are not observed within this fresh mass, as they are in the partly weathered zone, from which they roll out upon blasting. The shales of the upper zone have little grit when tried between the teeth.

A partial analysis of the shale from the Austin yard, made by Prof. C. S. Palmer, is given by Mr. Austin, as follows:

*Analysis of shale from Austin yard, Boulder.*

| | Per cent. |
|---|---|
| $SiO_2$ | 60.0 |
| $Al_2O_3$ | 18.0 |
| $Fe_2O_3$ | 4.75 |
| MgO | 2.0 |

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An analysis of a single selected lump (not a mixed sample) of the shale from Mr. Lee's yard, made by Mr. W. B. Stoddard, of Boulder, and furnished by Mr. Lee, is as follows:

*Analysis of shale from Lee yard, Boulder.*

| | Per cent. |
|---|---|
| $SiO_2$ | 63.309 |
| $Al_2O_3$ | 14.380 |
| $Fe_2O_3$ | 6.270 |
| FeO | .859 |
| CaO | 1.810 |
| MgO | 2.570 |
| $Na_2O$ | 2.190 |
| $K_2O$ | 1.280 |
| Loss by drying | 2.053 |
| Loss by ignition | 5.223 |
| | 99.944 |

PROCESSES OF BRICK MANUFACTURE.

The material is first loosened by blasting. Concretions are thrown out, chiefly to save wear in the crusher. They are said to be harmless in the brick if crushed sufficiently fine. In one of the three pits the black shale below is not reached. In another it is reached at the bottom, but not used. At the Austin works, on the north side of the city of Boulder, it is taken out and used along with the shale of the higher zone. It is harder, drier, and less plastic, and is therefore mixed with the partly weathered material. When thus mixed, no difference in the resulting brick can be detected, and there is no inconvenience in the manufacture. If properly ground, the unweathered black shale may be mixed with the weathered shale in equal parts. The blasting of this fresher shale in the autumn and its weathering or slacking through the winter has been tried, but no notable difference was produced.

The shale is crushed, screened, and pressed dry. Generally the moisture of the bank is sufficient for the pressing process. When the shale is too dry it is moistened in the crusher. No mud bricks are made.

The burning is in up-draft kilns, which generally have permanent walls for two-thirds or three-fourths of the height. One-half to two-thirds ton of local (Marshall or Louisville) coal per 1,000 bricks is used in the burning. Mr. Austin has installed a gas plant, and the project of burning with gas may be said to be on trial.

The shrinkage in both drying and burning of the best and strongest samples tested was but one-sixteenth inch in the height of the brick (4 inches), or less than 3 inches in the height of the kiln. Either by reason of difference in the clay or in the burning, this shrinkage varies at other yards to a maximum of three-sixteenths of an inch per brick, or 7½ inches in a kiln 40 bricks high.

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### QUALITY OF THE BRICK.

Standard tests made upon the red bricks by Prof. L. Duncan, of the University of Colorado, show an average crushing strength for the best brick equal to 4,100 pounds per square inch.[a] Supported at the ends (supports 6 inches apart) and loaded at the center, the same bricks showed a maximum fiber stress of 498 pounds per square inch. The same bricks absorbed water equal to 11.2 per cent of their weight in fifteen minutes, 11.6 per cent in thirty minutes, and 11.9 per cent in twenty-four hours. The promptness with which these bricks absorbed nearly the whole amount of water which they were capable of containing indicates largeness of the individual pores. The more rapidly water is absorbed, the more rapidly it is lost, and the probability that a sudden freeze should find the pores of these bricks filled with water is very small. This statement does not apply to bricks laid below the water line.[b]

No attempt has been made to make vitrified brick on a commercial scale at the Boulder yards. Experiments have been carried on in this line, and a very good brick resulted, but the shrinkage was great. In two tests it was seven-sixteenths inch and one-half inch in the height of the brick (4 inches).

### BRICKS OF LIGHT COLOR.

For several years past small quantities of light brick of a prevailing creamy color have been burned at the Boulder yards from clay brought by wagon from the coal-mining districts to the southeast. The first clay for this purpose was brought from Coal Creek. The largest amount has come from an abandoned coal mine at Marshall, from 3 to 4 feet of the clay being taken from the floor of the mine. More recently a number of samples from near Burnt Knoll have been tested, and encouraging results are reported.

Tests of light bricks from the Marshall clay gave a crushing strength about equal to that of the best red brick (4,090 pounds per square inch), a maximum fiber stress about two-thirds as great as that of red brick (332 pounds per square inch), and absorption slightly greater than that of the red bricks (12.5 per cent in twenty-four hours).

Red brick sell in Boulder at $7 to $9, the last-named price being for facing brick. The common price f. o. b. for shipment is $10

[a] This may be compared with the strength of one of the best-known building stones of the United States, the Bedford limestone of Indiana, which showed, in 17 tests, an average crushing strength of 4,326.7 pounds per square inch.—Twenty-first Ann. Rept. Indiana Dept. Geol. Nat. Resources, p. 317.

[b] See Buckley, E. R., Building and ornamental stones: Bull. Wisconsin Geol. and Nat. Hist. Survey No. 4, 1898, p. 20.

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per thousand. Buff brick have not been exported. They sell in Boulder at $20 per thousand.

Just beyond the western border of the area, near Sunshine, is a deposit of kaolin, much of which is to all appearances very pure. Probably the deposit is due to the alteration of feldspars in a pegmatite dike. The clay is white and without grit. Some of it is stony and contains kaolinite crystals. Upon grinding and wetting it becomes thoroughly plastic.

## COAL.

A small part of the northern Colorado coal field lies within the area here described. The whole field was carefully studied by Eldridge,[a] who has described the structure, discussed the quality of the coal, and correlated the seams of the different districts. Since the publication of his work, in 1896, several new mines have been opened, but these have revealed no structural relation not known and discussed in Monograph XXVII. The reader will find in that publication substantially all that is known in regard to the geologic relations of the coal.

## OIL AND GAS.

### SURFACE INDICATIONS.

The development of oil and gas in the Boulder area began in 1901, though their presence was suspected and rumored as early as 1867.[b] The early beliefs were based upon grounds which might now be regarded as far from demonstrative. The subsequent finding of oil must therefore be regarded largely as a piece of good fortune rather than the assured outcome of a safe business venture. The evidence consisted largely in the strongly bituminous odor of the Benton and Niobrara limestones and shales. It was therefore assumed that the strong-smelling rocks were themselves the reservoirs of petroleum, and in the first developments there was no thought of finding oil above these beds. Oil was found several thousand feet higher than these two formations, which have never produced anything of this nature. They have the same characteristic odor near the oil fields and far away. It was reasoned out with equal certainty that the Benton and Pierre shales must produce coal on account of their black color. In fact, it was while prospecting for coal in the Benton that the project of drilling for oil was first conceived.

A second class of surface indications, not found nearer than about 10 miles from Boulder, consists of seepages and "oil springs." The

[a] Op. cit., p. 345.

[b] A brief historical account of this industry is given by the writer in Bull. U. S. Geol. Survey No. 213, p. 322.

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fact that several such, most persistently reported, are on the Archean granite west of the foothill outcrops of stratified rocks shows that

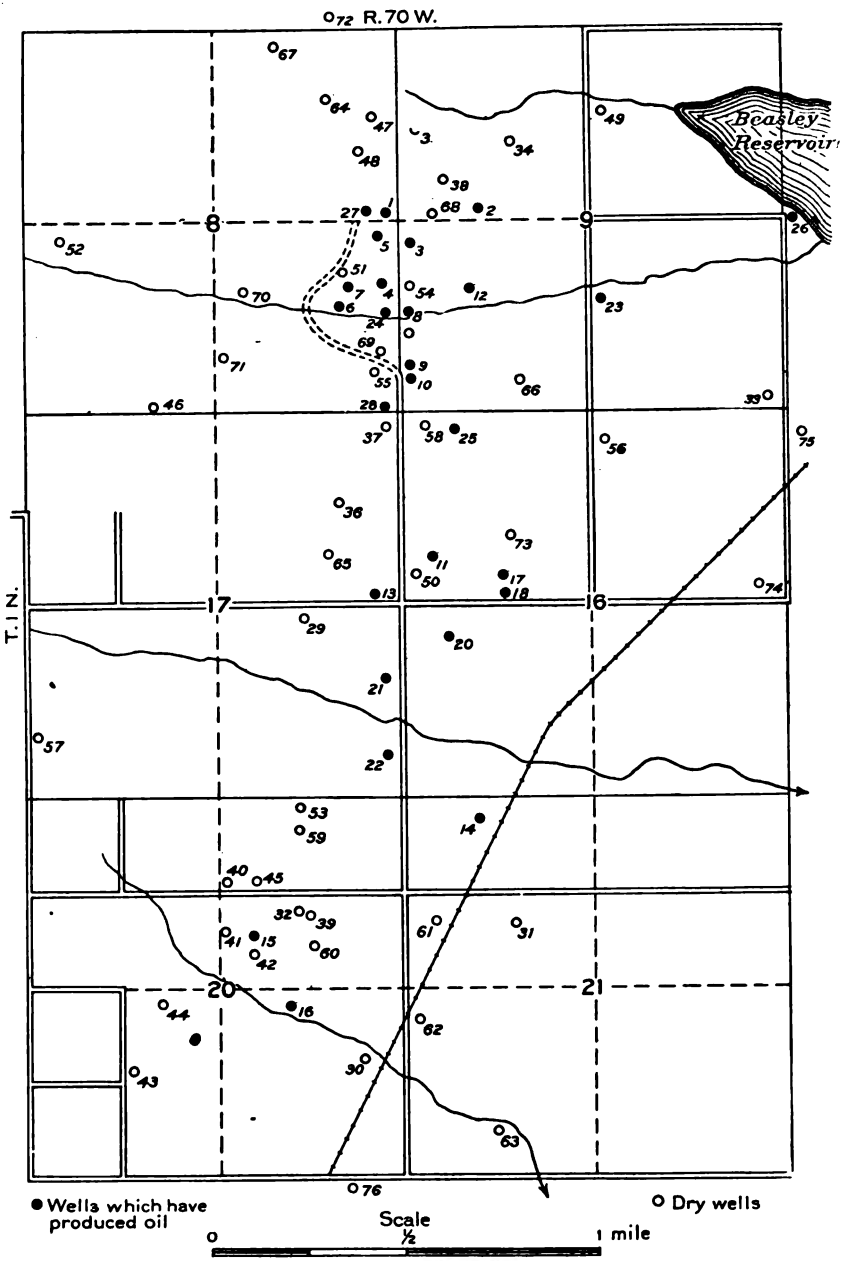



FIG. 9.—Map showing location of oil wells in the productive area.

the distinction between the various kinds of oily substances was poorly made. Some of the springs which issue from the Fountain

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red rocks are abundantly coated with oily matter at no great distance from the point of issuance, and these springs have been taken very seriously by oil prospectors, but in none of those examined was the odor of petroleum detected. The well-known oil spring on the bank of the Little Thompson, on the Culver ranch, 17 miles north of Boulder, issues from the heavy sandstone member of the Pierre, which has been called in this report the Hygiene sandstone. This is a seepage of petroleum.

### OIL-BEARING AREA.

On the evidence of these phenomena, corroborated by the positive behavior of "bobbers,"[a] several wells were drilled. In January, 1901, the McKenzie well, 3 miles northeast of Boulder, struck oil. Since that time there has been more or less drilling from Fort Collins on the north to Golden on the south. Sheet XII of Hayden's atlas has been freely used as "Hayden's oil map," and land underlain by his Colorado group (which includes the Pierre) has been well advertised as lying within "Hayden's oil belt." Development has been successful only within a limited area, the center of which is from 3 to 4 miles northeast of the city of Boulder and a little less than 3 miles east of the foothills. About 100 wells from 300 to over 3,400 feet in depth have been drilled within 5 miles of the McKenzie and about 20 more are scattered over the area between Fort Collins and Golden. Most of the wells (about 70) are within a rectangle 2 miles east and west by 3 miles north and south, comprising secs. 8, 9, 16, 17, 20, and 21, T. 1 N., R. 70 W. of the sixth principal meridian. Within this rectangle are all the producing wells except the Boulder Illuminating, a very small producer in sec. 10 only a few feet from the eastern boundary of the rectangle named, and the Buffalo gas well, which lies 1 mile south of the rectangle.

The following list gives the location of wells, the total depth, and the depth at which oil was found. The accompanying sketch map (fig. 9, p. 77) shows the locations of all wells within the productive area. Some of the dry wells are comparatively shallow; therefore in determining their significance their depths, as shown in the table, should be taken into account.

[a] The exact location of a large proportion of the wells of this field has been fixed by this means. The principle on which the use of the bobber rests is the same as that by which the proper site of a water well is determined by the involuntary turning of a witch-hazel sprout when held in the hand. In two instances, completed derricks have been taken down and removed to distances not exceeding 40 feet, because of the behavior of the bobber after their erection.

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*Wells in the Boulder district.*[a]

WELLS THAT HAVE AT SOME TIME PRODUCED OIL.

| No. | Name. | Depth. | Depth to oil. | Location. | | |
|---|---|---|---|---|---|---|
| | | | | Section. | Township. | Range. |
| | | *Feet.* | *Feet.* | | | |
| 1 | Bradford No. 1 | 2,404 | 1,810 | 8 | 1 N. | 70 W. |
| 2 | Boulder Valley | 2,050 T. | 2,010 | 9 | 1 N. | 70 W. |
| 3 | Boulder Valmont No. 2 | 1,960 | 1,650 | 9 | 1 N. | 70 W. |
| 4 | Otero No. 1 | 1,718 | 1,639 | 8 | 1 N. | 70 W. |
| 5 | Otero No. 3 | 1,905 | 1,807? | 8 | 1 N. | 70 W. |
| 6 | Otero No. 4 | | | 8 | 1 N. | 70 W. |
| 7 | Otero No. 5 | | | 8 | 1 N. | 70 W. |
| 8 | Savanna No. 3 | 1,763 | 1,584 | 9 | 1 N. | 70 W. |
| 9 | Savanna No. 4 | 1,475 T. | 1,468 | 9 | 1 N. | 70 W. |
| 10 | Savanna No. 5 (Younglove) | 2,005 | 1,980 T. | 9 | 1 N. | 70 W. |
| 11 | Dismuke | 2,070 | 2,064 | 16 | 1 N. | 70 W. |
| 12 | Orcini | | | 9 | 1 N. | 70 W. |
| 13 | McAfee No. 1 | | 2,105 T. | 17 | 1 N. | 70 W. |
| 14 | McKenzie | 2,585 T. | 2,537 T. | 21 | 1 N. | 70 W. |
| 15 | Republic No. 1 | 961 | 885 | 20 | 1 N. | 70 W. |
| 16 | Wellington | 2,461 | 2,423 | 20 | 1 N. | 70 W. |
| 17 | Bingham | | 2,845 | 16 | 1 N. | 70 W. |
| 18 | Arnold | 2,820 | 2,720 | 16 | 1 N. | 70 W. |
| 20 | Wisconsin No. 2 | 2,900 | | 16 | 1 N. | 70 W. |
| 21 | Crawford | 2,735 T. | 2,683 | 17 | 1 N. | 70 W. |
| 22 | Central | 2,621 | 2,551 | 17 | 1 N. | 70 W. |
| 23 | Two-ten | 2,141 | 2,111 | 9 | 1 N. | 70 W. |
| 24 | Otero No. 2 | 1,761 | 1,700 | 8 | 1 N. | 70 W. |
| 25 | St. George | | | 16 | 1 N. | 70 W. |
| 26 | Boulder Illuminating | 2,700 | | 10 | 1 N. | 70 W. |
| 27 | Bradford No. 2 | 1,720 | | 8 | 1 N. | 70 W. |
| 28 | Savanna No. 2 | 2,300 | 2,130 | 8 | 1 N. | 70 W. |

DRY OR NEARLY DRY WELLS.

| No. | Name. | Depth. | Location. | | |
|---|---|---|---|---|---|
| | | | Section. | Township. | Range. |
| | | *Feet.* | | | |
| 29 | McAfee No. 2 | 2,700 | 17 | 1 N. | 70 W. |
| 30 | Eagle | 2,740 | 20 | 1 N. | 70 W. |
| 31 | Alamo | 2,825 | 21 | 1 N. | 70 W. |
| 32 | Great Western | 1,600 | 20 | 1 N. | 70 W. |

[a] Numbers in the left-hand column refer to corresponding numbers on the sketch map (fig. 9). Wells not numbered are outside the mapped area. Depths marked T were determined by steel tape measure; most of the others by cable measure.

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*Wells in the Boulder district*—Continued.

DRY OR NEARLY DRY WELLS—Continued.

| No. | Name. | Depth. | Location. | | |
|---|---|---|---|---|---|
| | | | Section. | Township. | Range. |
| | | *Feet.* | | | |
| 33 | Planet No. 2 | 2,025 | 9 | 1 N. | 70 W. |
| 34 | Searchlight No. 2 | 2,480 | 9 | 1 N. | 70 W. |
| 35 | Home | 1,650 | 9 | 1 N. | 70 W. |
| 36 | Hayden No. 1 | 2,670 | 17 | 1 N. | 70 W. |
| 37 | Hayden No. 2 | 2,145 | 17 | 1 N. | 70 W. |
| 38 | Phoenix No. 2 | 2,400 | 9 | 1 N. | 70 W. |
| 39 | North Star | 1,160 | 20 | 1 N. | 70 W. |
| 40 | North Bend | 787 | 20 | 1 N. | 70 W. |
| 41 | Republic No. 2 | 1,008 | 20 | 1 N. | 70 W. |
| 42 | Republic No. 3 | | 20 | 1 N. | 70 W. |
| 43 | Homestake | 1,100 | 20 | 1 N. | 70 W. |
| 44 | Vindicator | 1,300 | 20 | 1 N. | 70 W. |
| 45 | Savanna No. 1 | 700 | 20 | 1 N. | 70 W. |
| 46 | Boulder Petroleum | 1,630 | 8 | 1 N. | 70 W. |
| 47 | Pioneer No. 2 | 2,160 | 8 | 1 N. | 70 W. |
| 48 | St. Julian | | 8 | 1 N. | 70 W. |
| 49 | Canfield | | 9 | 1 N. | 70 W. |
| 50 | Wood | 2,525 | 16 | 1 N. | 70 W. |
| 51 | Otero No. 6, now Rathvon No. 2 | [a] 3,575 | 8 | 1 N. | 70 W. |
| 52 | Wisconsin No. 1 | 2,000 | 8 | 1 N. | 70 W. |
| 53 | Cleveland | 2,492 | 20 | 1 N. | 70 W. |
| 54 | Savanna No. 6 | | 9 | 1 N. | 70 W. |
| 55 | Savanna No. 7 | | 8 | 1 N. | 70 W. |
| 56 | McAfee No. 3 | 2,580 | 16 | 1 N. | 70 W. |
| 57 | Chicago Banner | 2,600 | 17 | 1 N. | 70 W. |
| 58 | Langridge | 2,500 | 16 | 1 N. | 70 W. |
| 59 | Sale Boulder | | 20 | 1 N. | 70 W. |
| 60 | Me Edma | | 20 | 1 N. | 70 W. |
| 61 | Keystone | | 21 | 1 N. | 70 W. |
| 62 | Blue Jacket | | 21 | 1 N. | 70 W. |
| 63 | Boulder Basin | 3,300 | 21 | 1 N. | 70 W. |
| 64 | Independence | 2,550 | 8 | 1 N. | 70 W. |
| 65 | Palm | | 17 | 1 N. | 70 W. |
| 66 | Empire No. 2 | 2,500 | 9 | 1 N. | 70 W. |
| 67 | La Ford | 2,700 | 8 | 1 N. | 70 W. |
| 68 | Craig & Bartlett | | 9 | 1 N. | 70 W. |
| 69 | Savanna No. 8 | | 8 | 1 N. | 70 W. |
| 70 | Rathvon No. 1 | | 8 | 1 N. | 70 W. |

[a] Drilling deeper.

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*Wells in the Boulder district*—Continued.

DRY OR NEARLY DRY WELLS—Continued.

| No. | Name. | Depth. | Location. | | |
|---|---|---|---|---|---|
| | | | Section. | Township. | Range. |
| | | *Feet.* | | | |
| 71 | Hayden No. 3 | | 8 | 1 N. | 70 W. |
| 72 | Citizens No. 2 | 1,850 | 5 | 1 N. | 70 W. |
| 73 | Empire No. 1 | | 16 | 1 N. | 70 W. |
| 74 | Anderson | 2,684 | 16 | 1 N. | 70 W. |
| 75 | Peoria | 2,300 | 15 | 1N. | 70 W. |
| 76 | Phoenix No. 1 | | 29 | 1 N. | 70 W. |
| (a) | Citizens No. 1 | 2,500 | 25 | 1 N. | 71 W. |
| (a) | Maxwell No. 1 | | 24 | 1 N. | 71 W. |
| (a) | Maxwell No. 2 | 2,268 T. | 24 | 1 N. | 71 W. |
| (a) | Pioneer No. 1 | 2,700+ | 29 | 2 N. | 70 W. |
| (a) | King | 2,870 | 22 | 1 N. | 70 W. |
| (a) | Lafayette, Colo | 2,325 | | 1 N. | 70 W. |
| (a) | Planet No. 1 | 700 | | 1 N. | 70 W. |
| (a) | Searchlight No. 1 | 1,185 | | 1 N. | 70 W. |
| (a) | Monarch | 1,500 | 27 | 1 N. | 70 W. |
| (a) | Moore | 1,500 | 23 | 1 N. | 70 W. |
| (a) | Balkan | 1,000 | 29 | 1 N. | 70 W. |
| (a) | Boulder Valmont No. 1 | 2,740 | 22 | 1 N. | 70 W. |
| (a) | Rose Crude | 2,500 | 29 | 1 N. | 70 W. |
| (a) | Jasper | | 10 | 1 N. | 70 W. |
| (a) | Aurora | 3,006 | 10 | 1 N. | 70 W. |
| (a) | Amazon | | 15 | 1 N. | 70 W. |
| (a) | Carnahan | 3,105 | 18 | 1 N. | 69 W. |
| (a) | Hoover | | 35 | 1 N. | 70 W. |
| (a) | Martin | | 5 | 1 S. | 70 W. |
| (a) | Manhattan | 3,216 | 14 | 1 N. | 70 W. |
| (a) | Olean | 2,995 | 30 | 3 N. | 69 W. |
| (a) | Hygiene | 2,993 | 36 | 3 N. | 70 W. |
| (a) | Gardiner | 2,300? | 2 | 2 N. | 70 W. |
| (a) | Phenomenal | 2,150 | 6 | 1 S. | 70 W. |
| (a) | Thomas | 3,055 | 19 | 2 N. | 69 W. |
| (a) | Silver Lake (Stuart well) | 1,396 | 5 | 2 N. | 70 W. |
| (a) | Sternberg | | 33 | 1 N. | 70 W. |
| (a) | Pioneer No. 3 | | 34 | 1 N. | 70 W. |
| (a) | Prince No. 1 | | 27 | 2 N. | 69 W. |
| (a) | Prince No. 2 | | 27 | 2 N. | 69 W. |
| (a) | Buffalo (gas well) | 1,800 | 29 | 1 N. | 70 W. |

[a] Wells not numbered are outside the area of sketch map (fig. 9).



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The Savanna No. 9, in sec. 9, has reached at the present writing (October, 1904) a depth of 1,840 feet, where a good showing of oil has been encountered.

The Rathvon No. 2 (No. 51 on the map, fig. 9), already the deepest well in the field, is being drilled deeper.

### DRILLING IN THE PIERRE.

With few exceptions, the wells thus far put down have been drilled entirely in the Pierre. The exceptions are among the scattered wells to the east, which are on the very similar Fox Hills, or even on the Laramie, but these also traverse the Pierre for the greater part of their depths.

Drilling in this formation is comparatively easy and rapid. It is not uncommon to make 100 feet a day at considerable depths, and this is sometimes done without change of bits. On the other hand, slow progress is made in some beds. The average expense of drilling a well under contract with responsible parties is, at the present time, about $1.65 per foot for the first 2,000 feet. Below that depth the cost is greater. Under such contracts the owner of the well furnishes casing.

Surface water is usually encountered at a depth of about 15 feet and may be found in the first 100 or even the first 200 feet. Below this the wells are commonly "dry" or the seepage into the wells from the dense shales is so slow as to be of no significance in drilling. In isolated cases deep water-bearing strata are encountered, and such water is sometimes salt. At Lafayette, 11 miles east of the foothills, a well that was drilled for oil yielded a vigorous flow of water from several horizons between 400 and 700 feet deep. The oil from another well is mixed with about 10 per cent of salt water, which comes from just below the oil, and a slight admixture of salt water is found in at least one other well.

Many wells are cased only to the depth of the surface water. Others require 1,000 or even 2,000 feet of casing. In general, deep casing is not for the purpose of shutting off water so much as to avoid caving, which is common though not general. It has necessitated the abandonment of several wells.

### REPORTS RECEIVED FROM WELL DRILLERS.

By far the most common material reported as passed through is shale or "slate," occasionally varied as "clay" or "soapstone." Sand or "sand rock" is often reported. If it shows oil it is often called "the oil sand," with no particular reference to correlation with the sands of other wells. These sands are described on pages 31–33.

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Their composition is generally far from that which the name would suggest. They range from sand to clay, vary in thickness up to a maximum of over 100 feet, have a limited lateral extent, pass by gradations into the normal shale of the Pierre, and occur at any depth. One well may pass through five or six such beds, while another near by may penetrate nothing but shale to a depth of 2,000 feet. In drilling, the sandy beds are distinguished from the shales by their greater hardness, by the more rapid wear of the tools (the driller's chief criterion), and by the smaller amount of suspended matter in the water of the bailer. The washed-out samples commonly appear upon close examination as a collection of gritty shale granules, whose edges have been rounded under the drill. The better grades show an admixture of quartz grains, and exceptional beds are pure sand.

"Streaks" and "shells" are other terms used to indicate more than usual hardness at certain horizons. In the outcrops of these shales may frequently be detected hard beds a few inches or even several feet in thickness. They are either very calcareous or stained with iron oxide, or both, and owe their superior hardness to concentration of these substances. Such induration may affect the entire bed equally or may be concentrated into ellipsoidal concretions, which may be more or less separated, so that there are all gradations between the continuous hard plate and the isolated concretions. The word "shell" is suggestive of the concretions, as the word "streak" is of the plates, but in the reports the two words may be taken to be synonymous and alike indefinite. The comminuted fragments of these hard masses are not easily suspended in the water of the bailer, and probably for this reason, as well as on account of their superior hardness, are not infrequently reported as sand. On the other hand many of the so-called hard streaks are siliceous. The reports of "lime rock" are probably sometimes to be traced to the same occurrences, though, as seen on page 31, there are some true limestone beds in the Pierre.

### OIL-BEARING STRATA.

The beds from which the oil is obtained are the highly variable sands or sandstones, described above as varying between clay shale and silica sand. Such beds may be met with at any depth, but there is no depth at which such rock is certain to be found. Reports might indicate that it is slightly more abundant at a depth approaching 2,000 feet, but this may be due to the sharper lookout for sand as the well gets deeper. Not all of these strata contain oil or gas; some of the most porous sands give no indication of either.

While the thickness of such beds may be anything up to 100 feet

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or more, oil or gas may be obtained from only a part of their thickness. Such strata are plainly not so homogeneous as would appear from the bailings and, except locally, are far from being porous sandstones. Except in an oil well they would probably not be called sands at all. It is not uncommon to drill many feet into such strata and then strike a showing of oil or gas with no attendant change in the texture of the rock that can be detected in the bailings.

These small reservoirs of oil or gas seem mutually independent, being separated by the impervious shales. This isolation is well illustrated by the occurrence of deep veins of water in some wells and the absence of water from near-by sands in the same well or in adjacent wells. This mutual isolation of the several pockets is not accompanied by any great diversity in the character of the oils. With but few exceptions there is approximate uniformity, as shown by standard physical tests. Considering the striking uniformity of the great body of shales, this general likeness in the character of the oils is to be expected. Thus far there is but one authenticated instance in which the pumping of a new well has influenced the production of an older well. In this case the two wells are less than 200 feet apart. Curiously enough, these two wells found oil at depths differing almost 500 feet.

### SHOOTING OF WELLS.

All but one of the wells which were pumped previous to the close of 1902 were shot. In 1903 this practice was less general. The amount of nitroglycerin used in these shots has varied from 10 to 140 quarts. Dynamite charges have been as large as 500 pounds, 70 per cent nitroglycerin. The effects of these shots have not been uniformly favorable. The beneficial effects in a few of the best wells have doubtless been responsible for most of the later attempts. More recently a number of wells have begun pumping without being shot. The fact that the flow of some wells has decreased since the shooting will lead to greater caution, and it is to be hoped that it will lead to a more careful study of the nature and thicknesses of the strata passed through.

The beneficial or harmful effects of a shot must depend largely upon the texture of the stratum yielding the oil, for it seems to be true that some shales are compacted rather than shattered by the explosion. Supposably for this reason, shooting is not practiced in the Florence field, which, of all the older oil districts, the Boulder field most resembles. Owing to the difference in texture of the various beds yielding oil in the Boulder field, it is but reasonable to expect that the same shot which would prove beneficial to one well

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would be ruinous to another. On this account, if on no other, the texture and composition of the oil strata should be carefully studied by methods far more discriminating than the superficial ones first used in this field. It is but just to the companies and contractors now remaining on the ground to say that there has been much improvement in the character of well records.

A second reason for injurious effects from shooting lies in uncertainty about the exact depth of the sand which it is intended to shatter. Measurements of depths by steel tape are now becoming more common. In most of the earlier wells the depths of all formations are known only by cable measurement. It is not uncommon that the stated depths of important sands are thus liable to errors of 25 to 50 feet.

The possible injuries from a shot at the wrong place may be readily seen from the following consideration. If a porous rock is saturated with oil under pressure and is pierced by the drill, the oil is pressed upward in the hole solely because it has no outlet in any other direction, being surrounded (as in this field), or at least overlain, by impervious rocks. If this well is shot in such a way as to rupture the impervious rocks that surround the oil sand, the oil may leave the sand by other openings besides the well and may thus be dissipated in other porous beds and the well may be ruined.

Such an injurious effect may be produced even by shooting at the proper depth if the charge employed be too heavy. In one instance a well was shot at 740 feet with 500 pounds of dynamite, 60 per cent nitroglycerin. The formation above the sand was a uniform dense shale. A good quality of sandstone was blown from the hole in large chunks, one of which weighed 14 pounds. The shale was ruptured to the surface. Open cracks an inch or more wide extended for some rods from the well. It may be presumed that cracks also reached a considerable depth below the sand which was to be shattered. The well, of course, yielded no oil.

It can not be too carefully borne in mind that the one object in shooting is to shatter the rock which carries the oil and that only. With this object in view, it is plain that intelligent and discriminating shooting must depend upon the answers to the following questions: Is the oil stratum of such a texture that it will be shattered rather than compacted? What is the exact depth of its top (and bottom if drilled through)? How much of a shot will the overlying rocks bear without giving other outlets to the oil? This last question is one of great importance in this field. It is needless to say that such questions can be answered only by a carefully kept log and close study of samples, not only of oil sands but of all strata, in order to properly forecast their behavior under the influence of a shot.

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*Wells which were shot previous to June, 1903.*

| Name. | Charge of nitroglycerin. | Depth of shot, in feet. | Effect. |
|---|---|---|---|
| | *Quarts.* | | |
| McKenzie | 140 | 2,530–2,587 | No change. |
| Savanna No. 1 | 40 | | Abandoned after shot. |
| Savanna No. 2 | 100 | 2,115 | Intended to shoot at 2,100; abandoned after shot. |
| Savanna No. 3 | 50 | 1,579–1,600 | Reduced production from 10 barrels to 5 barrels. |
| Savanna No. 3 (second shot). | 100 | 1,579–1,600 | Produced about 7 barrels after second shot. |
| Otero No. 1 | 60 | 1,649–1,673 | Not pumped before; a good producer. |
| Otero No. 2 | 10 | 1,724–1,761 | Not pumped. |
| Otero No. 2 (second shot). | 60 | 1,724–1,761 | Little oil before; not pumped; a fair producer afterwards. |
| Otero No. 3 | [a] 10 | 1,600–1,900 | Shot four times; little oil. |
| Otero No. 3 (fifth shot). | 60 | 1,807–1,837 | Produced 3 or 4 barrels. |
| Bradford No. 1 | 100 | | Produced 4 or 5 barrels. |
| Bradford No. 2 | 30 | 1,650 | Went on drilling. |
| Bradford No. 2 (second shot). | 15 | 1,720 | Very small producer. |
| Boulder Illuminating. | 100 | | Not pumped before; a very small producer. |
| Crawford | 100 | 2,682–2,734 | Fair well before; ruined. |
| Boulder Valley | 80 | 2,021 | Increased production from 6 barrels to 15 barrels. |
| Hayden No. 1 | | 2,065 | Shot with 500 pounds dynamite, 70 per cent; no effect. |
| Do | 80 | Same depth. | Never pumped. |
| Central | 100 | 2,600 | A little oil; soon abandoned. |
| Two-ten | 120 | 2,111–2,141 | Not pumped before; small producer afterwards. |
| Hayden No. 2 | 40 | 2,135 | Never pumped. |
| Anderson | 40 | 2,670 | Do. |
| Wisconsin No. 2 | 40 | 2,035 | Small producer; drilled deeper and abandoned. |
| Boulder-Peoria | 80 | | Never pumped. |
| Independence | 60 | 1,100 | Do. |
| Boulder-Valmont No. 2. | 60 | 1,650 | Drilled deeper. |
| Boulder-Valmont No. 2 (second shot). | 60 | 1,947 | A fair producer. |
| Dismuke | 60 | 2,064 | Not pumped before; a small producer afterwards. |

[a] For each shot.

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*Wells which were shot previous to June, 1903*—Continued.

| Name. | Charge of nitro-glycerin. | Depth of shot, in feet. | Effect. |
|---|---|---|---|
| | *Quarts.* | | |
| Buffalo | 40 | 1,600 | No oil; did not affect gas production. |
| Republic No. 1 | 24 | 965 | Little or no change. |
| Republic No. 3 | | | Shot with 100 pounds dynamite; no change; dry hole. |
| North Bend | | 740 | Shot with 500 pounds dynamite, 60 per cent; hole ruined. |

## STRUCTURE OF THE OIL FIELD.

From all observations previous to the preliminary report made by the writer in January, 1903,[a] there appeared to be no law governing the distribution of oil in the Pierre shales. Small bodies of oil have been found in various parts of Colorado and neighboring States, but their structural relations, so far as known, afforded only vague explanations of their presence, and left the prospector with the impression that oil might or might not be found at almost any place in the Pierre.

The want of any known evidence of anticlinal arches suggested the inference that such structures were unnecessary to form receptacles for oil and gas in so dense a rock as the Pierre shales. The idea of some connection with folds was, however, not given up, and renewed efforts were made to induce companies and drillers to preserve samples and careful records, with a view to determining the exact position of the strata. During the summer of 1903 a detailed structural study was made of an area of 150 square miles, of which the oil field occupies the center.

It is a noteworthy fact that, with the exception of two very small producers, all the wells which have thus far produced oil are in a very narrow north-south belt. It is now known that this belt follows a monoclinal fold, the wells being near the top, and therefore in similar structural position to those of Ohio described by Orton as occurring on "arrested anticlines." The two very small producing wells, referred to above as located outside the narrow belt, are the Two-ten, one-half mile east, and the Boulder Illuminating, 1 mile east. It will be seen below (p. 92) that these wells occupy very significant positions with respect to another fold.

The monocline on which the wells are located is almost in line with an incipient échelon fold to the north-northwest, which affects the

[a] The Boulder, Colo., oil field: Bull. U. S. Geol. Survey No. 213, 1903, p. 322.

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foothill belt after the characteristic manner of such folds in this region. (See p. 43; also map, Pl. II.) For the present purpose it is best seen in the prominent offset in the outcropping edge of the Hygiene sandstone in sec. 6. The axis of this fold points east of south. In the outcrop of the same sandstone, but 5 miles farther northeast, a well-developed fold of similar character branches off, with an axis trending almost due south. Both these folds are described below. The monocline which determines the present line of producing wells is the southward continuation of the western and smaller one of the two flexures, but it is affected both in degree of flexure and in the direction of its axis by the stronger fold to the east.

It may be confidently affirmed that whatever may be the nature of the occurrence of oils elsewhere in the Pierre, there is nothing thus far known in the field at Boulder to offer encouragement to prospectors, except in intimate relation with folds. The essential features of this particular flexure should, then, be determined with care. Such a study may afford a basis for inference as to the probable oil-bearing or barren character of other similar structures occurring throughout a distance of 50 miles along the front of the range.

The form and location of these folds are best made clear by tracing the outcrop of the Hygiene sandstone (see p. 31), which made possible the discovery of the folds. Near Boulder the stratum is thin and weak and is separated from the Niobrara on the west by not more than 1,000 feet of shales. Seven miles north of Boulder it is 250 feet thick, and the Pierre shales below it have thickened to nearly 3,000 feet. As the dip has also greatly decreased within the same space, the sandstone outcrop has been carried nearly 2 miles to the east.

Stated more definitely, the outcrop forms a prominent cuesta (a ridge of abrupt scarp slope and long, gentle dip slope) running from the southwest corner to the northeast corner of sec. 6, T. 1 N., R. 70 W. This northeastward strike in sec. 6—an exception to the prevailing trend, which is almost north—is the surface expression of a mild tendency to échelon folding. It belongs to the same flexure as the monocline of the oil field, and its more prominent northwestward extension has been described on page 44. From the northeast corner of sec. 6 the outcrop extends north by east through the west side of sec. 32, T. 2 N. For nearly a mile north of this, in the vicinity of Lefthand Creek, the ridge is lost, but it reappears in the west half of sec. 20, running almost north. On the north side of this section the outcrop disappears under Table Mesa. If the mesa is crossed in a northeasterly direction, its northern side is reached in the middle of sec. 9. At this point the sharp crags of this sandstone are seen, forming a bold, bare ridge running far away to the northeast (N. 27° E.).

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If the mantle rock were removed from the mesa it is believed that the outcropping sandstone ledge would be seen to describe a great loop (see map, Pl. II) instead of cutting straight across from the point where it disappears under the southwest side to where it reappears on the northeast. The reasons for assuming such a structure will appear in a description of the outcrops.

As noted above, the strike for the last mile or two on the southwest side of Table Mesa is nearly north. Similarly on the northeast side, the ledge which approaches the plateau with a strike of S. 27° W. turns, just before its disappearance, to a direction differing only 8° from due south. The two outcrops, therefore, on the northeast and southwest sides would, if prolonged in straight lines, miss each other by about a mile.

There is a second outcropping ledge of sandstone on the south side of Table Mesa, a little more than a mile east of the one mentioned above, and about one-half mile west of Haystack Mountain. The sandstone of this eastern outcrop also forms a low ridge, and is to all appearances identical with that of the more westerly exposure. It shows the same succession of beds—a strong ledge of sandstone and a second horizon, a few hundred feet higher, marked by great calcareous concretions. (See p. 32.) The strike here is N. 35° W., and the dip is 10° to the northeast.

This low ridge abuts, as do those of the other outcrops, against the steep mesa scarp. It is believed that this line of outcrop is directly continuous with that which approaches Table Mesa from the northeast; that it represents the eastern limb of an anticlinal fold whose crest has been eroded away; that if the soil cover could be removed and the edge of the Hygiene sandstone everywhere exposed it would be found again dipping west on the western limb of this anticline a quarter to a half mile west of the eastern exposure; that the loop would be seen as represented in fig. 9, the outcrop crossing Table Mesa with a southerly trend from the middle of sec. 9, passing in a southeasterly course past Haystack Mountain, looping perhaps a mile to the south, then turning back to the north for 3 miles or more, then turning sharply around once more to the south along the course first described.

The structure here described is inferred mainly from dips, all of which within the area concerned agree with the features described. Although the Hygiene sandstone shows no good outcrop on the western limb of the anticline, westward dips as high as 18° are plainly seen within the sandy shales on the south side of Lefthand Creek near the line between secs. 28 and 29. At the north end of the canoe-shaped synclinal trough southward dips are found, according

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perfectly with the assumed structure. These may be seen along the high, level ditch skirting the northwest side of Table Mesa.[a]

Such an anticlinal fold as the one just described must die out gradually at the end. (See fig. 10.) If the axis be traced southward, the dip of the western limb should become less and less steep. At a certain point the westward dip will become zero; there will be a structural bench, as it were, interrupting the general eastward dip. This bench will be horizontal, except for a southward

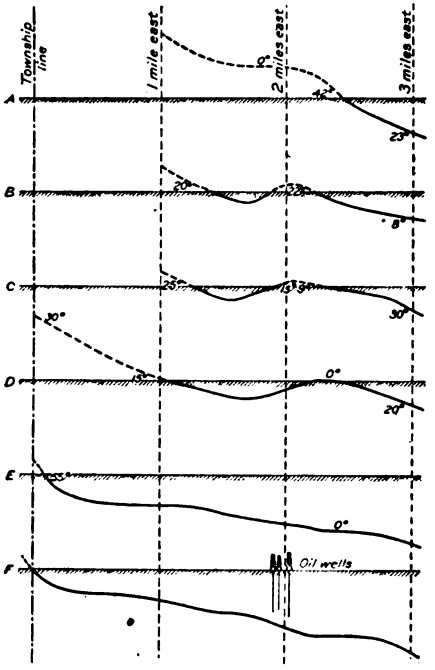



FIG. 10.—Cross sections showing the folding of the Hygiene sandstone. The straight horizontal lines represent the surface of the ground. The solid curve indicates the present position of the stratum, and the dotted curve indicates the position of the stratum before erosion. A, 10 miles north of the fortieth parallel, which is 1 mile south of Boulder; B, 9 miles north; C, 8 miles north; D, 6½ miles north; E, 5 miles north; F, 4 miles north.

inclination. Still farther south the whole will again dip toward the east, but in line with the axis of the anticline the dip will be smaller than either east or west of that line.

In the north side of sec. 9, T. 1 N., northwest of the Beasley reservoir, the only dip is one to the south, as is made apparent on the map

[a] This structure was first described by the writer in a paper entitled Structure of the Boulder oil field: Bull. U. S. Geol. Survey No 225, 1904, p. 383. Since that publication and since the above paragraphs were written Messrs. S. F. Rathvon and William Rathvon, oil operators, have had eight holes dug to ascertain the dip of the shales in sec. 33, T. 2 N., R. 70 W., and secs. 4 and 9, T. 1 N., and to verify the structure as described above. The results have fully confirmed the statements made here.

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by the outcropping of two arenaceous beds, the lines of outcrop having an east-west direction. This is on the axis of the larger fold. At this place the axes of the two folds (see p. 88) are in proximity, and the eastern and stronger fold uplifts the east side of the feebler western fold, making a horizontal bench out of what would otherwise be only a partial flattening of the general eastward dip. The result is seen on a line passing south through secs. 8, 17, and 20, along which the shales have no eastward dip. This belt is, however, narrow—a small fraction of a mile—and in short distances both east and west of it decided eastward dips appear.

Immediately east of this bench, perhaps on an average one-fourth of a mile, the producing wells are found. Their linear arrangement is all the more striking if the line be extended south to include the Buffalo gas well in the southeast corner of sec. 29. The position of the oil-producing strip is in exact accord with that of oil-producing belts of Ohio, where the conditions of occurrence have been made so well known by the very complete discussion of Orton.[a] The possible finding of other pools remote from such a structure need not be discussed here. They may or may not be found in structures differing from the one to which they are here related. It can only be said that the example of the already developed portion of this field offers no warrant for prospecting where these structural features are absent.

It may safely be assumed that the one significant feature in the structure of the oil field is the decided arrest of the general eastward dip. The peculiar relation of the two folds whose effects at this place unite to produce the result is not in itself taken to be significant, except in so far as it explains the occurrence or location of the one valuable feature. Further, it must not be assumed that this or any similar flexure will necessarily be oil-bearing throughout its whole length. Even very small transverse folds affecting the axis are sufficient to break up the deposit into so-called "pools." The intermittence of good oil territory along the line thus far developed, from secs. 8 and 9 on the north to the Buffalo gas well on the south, is already known. It can not therefore be assumed that one or two dry holes indicate that a line marked by the above-described structure is entirely barren.

### SUGGESTIONS AS TO FURTHER DEVELOPMENT.

If, then, the promise of future developments in this oil field be limited to a relationship with folds, it is highly important to exam-

[a] The Trenton limestone as a source of petroleum and inflammable gas: Eighth Ann. Rept. U. S. Geol. Survey, pt. 2, 1889.

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ine similar occurrences beyond the limits already developed. In the discussion, however, it must always be taken into account that the beds capable of containing deposits are small and of uncertain lateral extent. At the outset the further extension of the immediate group of productive wells demands attention. The axis of the fainter of the two folds, whose combined effects produce the monocline in and south of sec. 8, runs northward from the present developed field, but the very few exposures along this northern portion have not shown dips less than 6° or 7°, and therefore no close approach to the structure described above as occurring farther south, in the vicinity of the successful wells.

The stronger fold to the east completely neutralizes the general eastward dip as far south as sec. 4, while farther north it has a westward-dipping limb. The axis of this fold runs north by a little west through sec. 4, T. 1 N., R. 70 W., and secs. 33 and 28 of T. 2 N. The axis of this fold has not been tested by the drill. At its southern extremity, however, where the strata begin to dip strongly southward (10° or 15°), is the Two-ten well, and one-half mile farther east is the Boulder Illuminating. Both of these wells are small producers (about 2 barrels a day from each well), but the finding of oil, even in small quantities, in this relation to the fold is significant. From a structural standpoint it may be expected that if larger quantities of oil are present they will be found nearer the axis of this fold rather than farther away.

Sheet No. XII of Hayden's Atlas of Colorado shows with considerable detail a series of large échelon folds, but those described above are, in general, too small to appear on that map. The salient curve in the Dakota, however, shown on the Hayden map north of Left-hand Creek, must be correlated with the long loop in the Hygiene sandstone described above. If this latter formation were drawn on the Hayden map, the loop in question would be three-fourths of an inch long. A fair idea of the relative sizes of such folds may be had by comparing the effects of each on the same formation, as, for example, on the Dakota.

The question of stores of oil in the larger folds naturally suggests itself, in view of the known relation of oil to the smaller. It is to be remembered, however, that in the Appalachian region it is not the great anticlines which have conserved the hydrocarbons. Here, as there, the greater deformations may prove to have made poor reservoirs, probably by the opening of cracks. Nor, indeed, has it yet been shown that the larger of the small folds in the Boulder field is an oil reservoir. If the future proves otherwise, there will be a strong presumption in favor of restricting the search for oil to folds of the smaller order. If the large folds shown on the Hayden map

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are to prove oil-bearing, it will probably be in their remote ends, where the fold is dying out on the plains.

A condition of this nature has been put to the test in one instance. A fine fold of this kind, north and east of Lyons, flattens out in the vicinity of Hygiene (about 12 miles north and 5 miles east from Boulder). Here, in a line transverse to the axis, three wells were drilled to depths approximating 3,000 feet. They were not without showings of oil, but a better showing was obtained 4 miles farther down its axis to the southeast, where the fold has flattened greatly and was probably never considered a factor. Oil from a depth of about 600 feet has also accumulated in an abandoned water well, a mile north of Hygiene. This is also on or near the axis of the fold.

If the larger folds fail to yield oil, the one remaining hope (probably more promising from the start) lies in the smaller folds. For reasons given above, these, in so far as they affect the Pierre shales, are betrayed only by the most obscure outcrops. Yet it is in this formation, at a distance of a few miles from the harder rocks of the foothills, that folds must be found if they are to serve as guides in prospecting for oil.

Herein lies the large significance of the similar though often very small flexures which affect the stronger and well-exposed strata of the foothills from Morrison to Niobrara, inclusive. In these stronger rocks they may be very small, the looping back generally being less than a quarter of a mile; but the same stress will be found to have produced larger results in the weaker Pierre. Therefore, if the Pierre shales are to be prospected in this region of échelon folding, much time will be saved by making a preliminary examination of the stronger strata. Where the Hygiene sandstone is exposed, it is the natural index of structure and the best. Where it does not outcrop, the basal Niobrara limestone is the nearest criterion.

In these suggestions no account is taken of the possibility of folds running strictly parallel to the foothill outcrops. This is of course possible, especially south of Boulder, where the échelon type is not prevalent. The lines of procedure suggested above are only those which have been derived from the known structure of the already developed field. They are not intended to exclude consideration of structures not yet exemplified.

The Maxwell gas well, less than 2 miles north of Boulder and a little more than half a mile from the Pierre-Niobrara contact, may seem an exception to all that has been said above regarding the location of oil and, by inference, of the closely associated gas. It might therefore be thought of as putting the generalization to a severe test. Near-by outcrops are too few and unsatisfactory to fix the structure with any definiteness, but it is a remarkable fact that this well lies

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south-southeast from an incipient échelon fold which affects the boundaries of all outcrops from the Lykins to the Benton. (See p. 43.) The axis of this fold would seem to pass a little west of the Maxwell well.

### SOURCES OF THE OIL.

The strata containing the original substances from which the oil of the Boulder field has been derived are not determined with exactness. Much of the Pierre is black with disseminated carbonaceous matter. The Niobrara below is bituminous, yielding a strong odor, especially from its more fossiliferous beds. The same is true of the Benton, whose shales are characteristically dark, and whose bituminous odor is at least as well marked as that of the Niobrara. The Dakota bears oil in Wyoming, and an asphaltic substance oozes from its cracks at various places from Wyoming to southwestern Colorado. Even the Morrison beds contain some oil, as seen near the Florence field.

The strata thus enumerated have a combined thickness of from 5,000 to 6,000 feet below the horizon of the lowest oil reached in the Boulder field. The Benton and Niobrara are doubtless richer in organic matter than any higher strata and surely far richer than anything below. While these considerations are favorable to the beds below the Pierre as the ultimate sources of the oil, others favor a source not far from the horizon at which the oil is found. Neither hypothesis is established and neither can yet be abandoned.

The great density of the Pierre shales must make them a serious barrier to the passage of any form of matter. It is significant that the same dense shale which forms the so-called "cap rock," and is therefore considered impervious to oil or gas, also underlies the oil, and must therefore have been traversed by the hydrocarbons for thousands of feet if the ultimate source of these substances was in the Benton and Niobrara. It is also noteworthy that some of the purest white friable silica sand found in deep wells has contained no oil. Such sands must have been quickly discovered by the rising hydrocarbons working their way upward from great depths through the scanty pores of the shale. Both the general density of the shales and the absence of the oil from certain friable sands favor a hypothesis which locates the original source of the oil at horizons not very far from those at which it is now found. In this case it is safe to say that the tilting of the beds has given opportunity for the segregation of their fluids according to their several specific gravities. Theory would require that the oil should be found just about where the present wells are located; that is, on the slope below the horizontal bench. The summit of the monoclinal slope, or edge of the structural

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terrace, should be the approximate western limit of gas, or of oil, if there be little gas present. This is because fluids lighter than water, after rising through an inclined porous stratum to this line, could find no higher place to go.

A similar segregation might occur in beds whose dips are not interrupted by a horizontal bench. If oil, in mounting to higher levels through such porous beds, finds them gradually changed to dense shales, there must result an accumulation along the upper margin of the porous portion, regardless of folds and interrupted dips. It is not improbable that small accumulations of this kind exist in the Pierre shales and may in the future be found. The chance that such may exist is independent of the original source of the hydrocarbons. It matters little whether this was near the horizon of the oil-bearing strata or thousands of feet below.

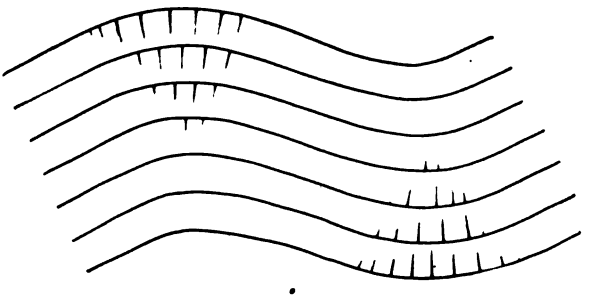


FIG. 11.—Hypothetical cracking in the formation of the oil-field monocline.

The suggestion of a deep source for the original constituents of the oil, based on the bituminous character of the Benton and Niobrara beds, is so strong that any plausible explanation of its rise through the Pierre shales deserves consideration. While in general highly dense, it is not certain that the Pierre shales directly below the known oil deposits are unfractured. If affected by fracture they may not be so impervious as would be inferred from a study of samples. The folding along this belt may have had more significance than the making of suitable closed reservoirs in which to hold the oil. At the foot of such a monoclinal offset as has been described, the lower strata might well be expected to be stretched and those above compressed. (See fig. 11.) At the top of the monocline, the reverse is true; the upper beds should be stretched and those below compressed. If such folding, therefore, is to result in greater permeability of the lower beds along any belt, it must be along the

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foot of the monoclinal slope. From all observations in this field, this tendency to fissuring in the deeper beds might well be the chief significance of the monocline. It has been pointed out above that the axis of the oil-producing belt so far as explored is a full quarter of a mile east of the north-south line along which the shales are horizontal. The dip of the shales through which the producing wells are drilled approaches 20°. Assuming the folds of the lower strata to be similar to those above, and remembering that no reservoirs of gas have been found, which might be expected to crowd the oil down the slope, this situation of the oil deposits does not favor the analogy of the anticlinal reservoir. It seems to suggest that the foot of the monoclinal slope may be quite as important in relation to the accumulation of oil as is its top.

There are here, therefore, two possible ways in which folding may have affected these oil deposits: (1) It may have provided suitably constructed reservoirs; (2) it may have made the deep rocks sufficiently permeable to allow the ascent of hydrocarbons from the lower formations whose constitution makes them the most plausible sources. If the deeper origin be assigned to the oil, then the second consideration is more urgent in this field than the first, though the two are quite consistent. The second consideration provides for communication (otherwise seemingly impossible) with the most bituminous beds of the region. It also localizes the upward movement of the hydrocarbons along lines of fracture, thus accounting for the absence of oil and gas in some of the most porous sands. It also harmonizes well with the situation of oils far down the monoclinal slope. Finally, such a structure in a mass of shales containing occasional sandy beds would result in accumulation at very diverse depths. Fractures leading up from below would here strike and there miss sands of limited lateral extent, just as the wells reaching down from the surface have done.

The stretching and possible fracture of the deeper beds at the foot of a monoclinal slope are, of course, not open to observation. The corresponding process in the upper beds at the top of the slope has left the marks which were to be expected in this field. A considerable amount of fracturing is evidenced by calcite vein filling. In the SE. ¼ sec. 6, T. 1 N., R. 70 W., where there is the incipient échelon fold that has been described (map, Pl. II), the north side of the mesa shows broad exposures of the bare shales. The weathering and erosion of these has left the surface strewn with chunks of calcite which occupied the crevices of the shale. These veins are often several inches wide. Similar evidence is seen just west of the oil wells, where the horizontal position of the shales gives way to the eastward dip.

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It is not intended to suggest that the lower beds at the foot of the monoclinal slope could be affected by open fissures. The necessary depth to which permeability, resulting from deformation, must be extended in order to reach the Niobrara and Benton is even now well above half a mile, and it may have been one or two thousand feet more at the time the folding took place (assuming subsequent denudation to that amount). At such a depth it is not to be expected that crevices in shale will open wide; indeed, the plausibility of the entire supposition here sketched depends upon the possibility of any fracture at all. However, inasmuch as the shale, when perfectly fresh, is a fairly strong rock, it seems at least probable that deformation within the zone concerned would be by fracture rather than by flowage. Still the connection between oil accumulation and permeability caused by folding can not yet be affirmed. Some questions remain to be answered before this supposition can be made a working hypothesis.

### PHYSICAL PROPERTIES.

In physical tests the products of the different wells show a noteworthy resemblance, despite the diverse depths from which they are derived. There are minor differences in color, but in general the oil is a light amber and has a paraffin base and an agreeable odor. Gravity tests range from 42° to 44.6° Beaumé. In all flash tests reported the oil has flashed below 60° F., and the exact temperature of the point was therefore not recorded. The proportions of the more valuable products of refinement, notably that of kerosene, are very large. The current price of the crude oil, $1.10 per barrel, is the best indication of its quality from a commercial point of view. It is said by Oliphant to be the best oil west of Mississippi River.[a]

### PRODUCTION OF OIL AND GAS.

As stated above (p. 77), there are nearly 70 wells in the productive area, though this number includes some very shallow holes. Twenty-eight have pumped oil at some time. Twelve of the 28 were abandoned before October, 1904, and a few others were not at that time pumped with any regularity.

The oil production amounted to 11,000 barrels in 1902 and 39,000 barrels in 1903. While a very substantial gain is thus indicated when the output is stated by years, the monthly production at the close of 1903 was smaller than at the beginning of the year. The average daily production for 1904 did not exceed 70 barrels.

[a] Mineral Resources U. S. for 1902, U. S. Geol. Survey, 1904, p. 562.



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One gas well, the Buffalo, in the southeast corner of sec. 29, and therefore in the same north-south line with the oil wells, but farther south, has yielded considerable quantities of gas for several years. The gas is piped to Boulder and was at first used in connection with the manufactured gas. Since September, 1903, no gas has been manufactured, and the quantity of gas used from the well has been gradually increased. The rate of consumption has at times been nearly 3,000,000 feet per month. It is probable that the present rate of consumption could not with safety be greatly increased, but no diminution of the capacity of the well has yet been observed. Its quality is very satisfactory.

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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

# PALEONTOLOGY

OF THE

# MALONE JURASSIC FORMATION OF TEXAS

BY

FRANCIS WHITTEMORE CRAGIN

WITH

STRATIGRAPHIC NOTES ON MALONE MOUNTAIN AND THE SURROUNDING REGION NEAR SIERRA BLANCA, TEXAS

BY

T. W. STANTON



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UNITED STATES GEOLOGICAL SURVEY,
*Washington, D. C., February 4, 1903.*

SIR: I transmit herewith, for publication as a bulletin of the Survey, a manuscript entitled "Paleontology of the Malone Jurassic Formation of Texas," by Francis Whittemore Cragin. Professor Cragin prepared a large part of this paper in 1899, beginning the work while he was a graduate student in Johns Hopkins University, Baltimore, and continuing it here under my supervision in accordance with authority obtained from you at the time. I have inserted a sketch of the stratigraphy of the region and have prepared the accompanying map, using data furnished by Professor Cragin for the portion of the region referred to in his text.

I may add that Professor Cragin's collection of Malone fossils is now the property of the United States National Museum.

Very respectfully,

T. W. STANTON, *Paleontologist.*

Hon. CHARLES D. WALCOTT,
*Director United States Geological Survey.*



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# PALEONTOLOGY OF THE MALONE JURASSIC FORMATION OF TEXAS.

By F. W. CRAGIN.

## INTRODUCTION.

### SCOPE OF INVESTIGATION.

This paper embodies the paleontological and some geological results of recent studies in the Jurassic of El Paso County, Tex. It is in part the outgrowth of one of briefer scope, prepared in 1897–98 from collections and data obtained by me in a reconnaissance made in 1897, and supplemented by some of the results of the earlier work of Messrs. Taff, Wyschetzki, and Goodell, as explained below. In its present form it includes also the study of two collections made by Dr. T. W. Stanton, of the United States Geological Survey, as noted more particularly elsewhere herein.

### GEOGRAPHY OF THE REGION.

In El Paso County, a few miles north of the Rio Grande and 75 to 80 miles southeast of El Paso, is a narrow ridge known as Malone Mountain. Its trend is nearly north-northwest and south-southeast, and is nearly continuous with that of the northwestern end of the Quitman Mountains, from which it is separated by an interval of less than a mile. At the eastern base of the mountain, near its northern end, on the joint line of the Southern Pacific and Texas Pacific railways is the flag station of Malone, which has an elevation of 4,262 feet above sea level.[a] Also on this line of railway, and between 2 and 3 miles west of the north end of Malone Mountain, is Finlay station. As shown by the Fort Hancock sheet of the Topographic Atlas of the United States, in preparation by the United States Geological Survey, the mountain rises to somewhere over 5,050 feet above sea level, and so has a relative altitude of about 800 feet. On either side of the mountain ridge are hills that are geologically related to the mountain.

[a] Gannett, Henry, Dictionary of altitudes in the United States, third edition: Bull. U. S. Geol. Survey No. 160, 1899.



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## HISTORY OF GEOLOGICAL STUDIES.

The geological observations made along this part of the Rio Grande Valley in the fifties by the Mexican Boundary and Pacific Railway surveys were but cursory, and did not specifically include the Malone district, and the first serious geological study within the district was made in 1890 by the Geological Survey of Texas, under Mr. E. T. Dumble. In that year Mr. J. A. Taff, then attached to Mr. W. H. von Streeruwitz's Trans-Pecos division of that survey, studied Malone Mountain, and Mr. Ralph Wyschetzki, of the same division, collected a few fossils from the hills northeast of it. In the second annual report of the same survey, issued in 1891, Mr. Taff published and discussed a section of Malone Mountain and described, with scant allusion to its paleontology, an essential part of the Malone formation, consisting of limestone, gypsum, and flagstone of Malone Mountain, which he called the "Malone beds." He thus virtually recognized the formation, his name for which, as the earliest proposed for it, is here retained; but he erred in placing it in the Washita Cretaceous division together with his Etholen and Yucca beds, which are typically seen in a part of the Etholen Knobs and Yucca Mesa, and are of Glen Rose age. Mr. Taff also correlated the sandstone and oyster-shell breccia of the Etholen Knobs with the Malone formation, but these, like the Etholen breccia-conglomerates and the Yucca beds, belong to the Glen Rose alternating beds.

In 1893 I described[a] the better part of a small collection of fossils which Mr. Wyschetzki had obtained from the hills northeast of Malone Mountain. Disregarding for the moment a strong suspicion that these fossils were Jurassic, I described them as Cretaceous, since the time and material then available were too limited for a conclusive study, and since it was thought that the small Malone fauna then known had one species in common with the Cretaceous, in *Trigonia taffii*, which occurred with undoubted Cretaceous fossils on Bluff Mesa and was supposed to have been found in the Malone district also.[b] But I resolved to take up the question at the first opportunity that should offer.

[a] A contribution to the Invertebrate paleontology of the Texas Cretaceous: Fourth Ann. Rept. Geol. Survey Texas, pt. 2, pp. i–lv, 139–246, and Pls. XXIV–XLVI.

[b] The material thus treated included six new species, which were described under the following names: *Anatina tosta*, *Cucullæa transpecosensis*, *Cyprina streeruwitzii*, *Trigonia ryschetzkii*, *Trigonia taffii*, and *Venus malonensis*. It was afterwards found that *Trigonia taffii* does not occur at all in the Malone formation, but is a fossil of the Glen Rose alternating beds, to which Bluff Mesa belongs. The type material of *Trigonia taffii* was described (loc. cit., p. 214) as having come in part from Bluff Mesa and in part from the locality of *Trigonia ryschetzkii*, east of Malone. It is now, however, practically certain that the nearly complete valve from Bluff Mesa alone represented *Trigonia taffii*, and that all of the fragmental material which was supposed to belong to this species, and which was from the Malone locality, belonged—as part of it which I recently had opportunity of reexamining certainly does—to *T. ryschetzkii*. All of the very diligent collecting done at the Malone locality by Doctor Stanton and myself, while showing the occurrence of *T.*

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No opportunity for further investigation of the Malone fauna was presented until 1895. In March of that year the late Mr. Robert W. Goodell, assisted by his father, Mr. R. R. Goodell, made a journey to Guaymas, Mexico, to obtain recent marine invertebrates from some rich collecting grounds on which I had worked in the winter of 1882–83. In returning, he very kindly undertook to visit Sierra Blanca and Quitman mountains, Bluff and other mesas, and the hills north to east of Malone, to seek further evidence concerning the age of the rocks that had yielded the Wyschetzki collection. From the Sierra Blanca Mountains and several other of the elevations visited, which did not include Malone Mountain, the Messrs. Goodell brought back a large number of fossils, all of which were of the Comanche series save those from the hills a mile and a half east of Malone station. Those from the latter locality included, besides several of the species obtained there by Mr. Wyschetzki in 1890, some specimens which the writer recognized as specifically identical with the Mexican Jurassic fossil, *Pleuromya inconstans* Castillo and Aguilera, and one example of an undescribed Trigonia of the Jurassic section Undulatæ. A restudy of *Trigonia vyschetzkii*, of which the Messrs. Goodell had obtained new material, led me to the conclusion that the affinities of that fossil also were Jurassic rather than Cretaceous. In 1896–97, therefore, I prepared a brief paper on the "Discovery of marine Jurassic rocks in southwestern Texas," assigning to the Malone formation a stratigraphic place somewhat different from that given to the original "Malone beds" of Mr. Taff, and announcing its Jurassic age. This article, which included, from the field notes of Mr. Robert W. Goodell, the latter's section of the hills northeast of Malone station, was published in the Journal of Geology, Volume V, pages 813–820.

It was noted in this article that a comparison of the observations of Mr. Goodell with those of Mr. Taff seemed to show petrographical grounds for a formational correlation of the hills northeast of Malone station with the Malone beds of Malone Mountain. Such correlation, for a part of these hills and a part of the mountain, was confirmed paleontologically by me in August, 1897, when I visited El

*vyschetzkii* in profusion, has failed to yield a single fragment of the *T. taffi*. On the other hand the fauna with which *T. taffi* is associated was examined by Doctor Stanton and by me in 1897, both by a joint excursion to Bluff Mesa and by our independent examinations of the W. F. Cummins Red Bull Canyon collection in the museum of the Geological Survey of Texas, and was found to include, with some species hitherto undescribed, others of the Glen Rose Cretaceous.

In 1894 Mr. Cummins made a collection of fossils, including *Trigonia taffi*, near the southern end of the Quitman Mountains, labeling it "Mule Canyon." An excursion to Mule Canyon was made by Doctor Stanton and myself in 1897, but the fossiliferous rocks in its vicinity were found to contain Cretaceous fossils unlike those collected by Mr. Cummins. Further search by Doctor Stanton in 1898 resulted in his discovering the locality of the Cummins collection, which was found to be Red Bull Canyon, the designation, "Mule Canyon," having been used by Mr. Cummins on his labels through some inadvertence.

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Paso County, Tex., and found that certain fossils were common to the locality a mile and a half east of Malone station and to the southeastern quarter of Malone Mountain, and in September of that year and in the summer of the year following, for the mountain in general and its western foothills, by Dr. T. W. Stanton, who found for these and the eastern foothills an essentially common fauna.

I arrived at Sierra Blanca station August 19, 1897, and remained till September 7, reconnoitering in several directions from that station as headquarters and giving the greater part of my time to the Malone district. I examined parts of the eastern slope of Malone Mountain, from which also I obtained a few fossils, and observed, from the southern part of the mountain crest, the general relations of the western foothills. But it was to the eastern hills, as including the locality that had yielded the interesting fossils to Mr. Wyschetzki and the Messrs. Goodell, that I gave chief attention; and from these hills I made a large collection of fossils. The western slope and foothills of the mountain I was unable to explore for lack of time.

On September 2 Doctor Stanton reached Sierra Blanca and joined me in exploring and collecting for a few days, both in Cretaceous localities and in the eastern part of the Malone district. Doctor Stanton remained in the field after my departure and carried reconnaissance further westward than I had, examining the western slope and foothills of Malone Mountain and making a section of the mountain. In the summer of 1898, with more time and better facilities at his disposal than had been available to either of us in 1897, Doctor Stanton returned to this part of Texas and made additional collections and a comprehensive examination of the Malone and contiguous territory. Later, with the consent of the Director of the United States Geological Survey, Doctor Stanton very generously turned over to me for study and description all of the marine fossils collected by him from the Malone formation in his two expeditions. Doctor Stanton's geological observations will be given by himself in another connection herewith.

The types collected in the Malone district by the Geological Survey of Texas in 1890 and described in the fourth annual report of that survey have in part been loaned to the United States Geological Survey by Doctor Dumble and used in preparing this paper. Most of the species thus early collected are represented by ampler material from later collections. The more important of the specimens of the Goodell Malone collection, which were given to me by Mr. Robert W. Goodell in 1897, and my Malone collection, made in the latter year, have recently become the property of the United States National Museum and, first studied in the summer of 1898, have been restudied in connection with the other material. The material on which these

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paleontological studies are based therefore includes, with the exception of three or four mislaid specimens, all of the marine fossils that have hitherto been collected in Texas from rocks of the Malone formation.

## GEOLOGY OF THE REGION.

All of the fossils described in this paper are from Malone Mountain and neighboring hills, and from within a few miles of the railway stations of Malone and Finlay. The greater number were obtained from east of the mountain, in the range of low hills which, in my article on "Discovery of marine Jurassic rocks in southwestern Texas," I called the Malone Hills.

Beginning about half a mile north of Malone station, and in part too low to be indicated by the contour lines, with 50-foot intervals, used in the general topographic map of this region, these hills extend, trending at first about eastward and later more southeasterly, as a practically continuous Jurassic outcrop through the Neocene, for a distance of a mile and a half. At a mile to nearly a mile and a half from the station they include a line of three connected hills (*C*, *D*, and *E*, on Pl. I, in order of distance from the station), which may be called the Trio. As best observed on the southeastern quarter of hill *E*, the Trio geological section comprises three natural subdivisions, the lower, middle, and upper of which respectively may be designated as Theta, Iota, and Kappa.

The Theta subdivision of this section consists chiefly of sandstone, with occasional courses of more or less sandy varying to relatively pure indurated limestone and some clay. The sandstone and clays are of a gray and yellowish-brown color, sometimes varying to purple and red. The purer of the limestone layers have a bluish-black color, weathering to gray or brown. Bedded and irregular seams of white cleavable calcite, sometimes several inches thick, here traverse the Theta in its upper part. The base of the Theta is not exposed.

A short distance southeast of hill *E* is a very low truncate mound (*F*), from which the Kappa subdivision had been removed by erosion before the prevalence of the Neocene waters which have so widely mantled the lower levels of this region with tufaceous cements and conglomerates. The mound is gently synclinal in structure and consists of a few feet of Iota conglomerates rising rather abruptly from gentle basal slopes. A Theta outcrop of only a few acres, lying chiefly in the interval between hill *E* and the Truncate mound, but extending also around the latter except on its east to southeast quarter, and embracing so much of the basal slopes of both elevations as has been denuded of its Neocene mantle, is by far the richest collecting ground in the Malone district. This interval is of anticlinal structure, the strata increasing their dip from either the neighboring base

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of the Trio or that of the Truncate mound toward a common line, the axis of a closed fold, where they stand nearly vertical, and where is the shallow beginning of a small draw that deepens to the northward. This pinching and change of dip make difficult a close estimate of the thickness of upper Theta strata here exposed, but it does not seem probable that less than about 250 feet of these can have been involved in the exposed portion of either limb of the fold.

If we except obscure vestiges of fossils in the Kappa limestones and fragments of Paleozoic fossils (partly corals) in the pebbles of the Iota conglomerates, the fossils at this locality are confined to the Theta subdivision.

A very few forms, two or three of them identifiable as the commonest Malone species, were collected in the upper part of the Theta, chiefly in one bed of slight thickness, at a spot near the southwestern base of hill *C*, at the south border of the flat, saddle-like interval that separates the Trio from the west-northwestward continuation (*A*, *B*) of this hill range. In the immediate vicinity of this minor occurrence of fossils, and stratigraphically lower, is a small exposure of gypsum. This locality is only about half a mile west and a little north of the principal collecting ground above described.

The Iota subdivision of the Trio section consists distinctively of coarse conglomerates, in six or more beds 1 to 8 feet thick, separated by layers of relatively soft sandstone. Many of the pebbles and cobbles in these conglomerates are of iron-stained chert and siliceous limestone; some are evidently of Paleozoic derivation, and a few are of white quartz. In the southeastern slope of the east hill of the Trio the thickness of the Iota is about 50 feet. In the Truncate mound a considerable part of the original thickness has been removed. The dip of the Iota, like that of the other and generally much disturbed members of the Malone formation, is extremely variable in amount and direction. In the Trio and the Truncate mound it is usually from 15° to 25°, but exceeds the latter amount in places. On the southeastern slope of the Trio its direction is a few degrees west of north; in the east and west walls of the Truncate mound it is, respectively, west and east.

At the isolated hill (*G*) south of the railway, between one-half and three-fourths of a mile southeast of the main fossil-bearing locality, no fossils were found, nor any Malone rocks lower than Iota, though the typical succession of conglomerates of the latter subdivision is shown there, blanketed by Neocene at its base.

The Kappa, which forms the upper portion of the Trio—about 40 feet in hill *E*—is of hard, massively bedded, bluish-black, calcite-seamed limestone, charged with irregular segregations or impregnations of silica and iron. Much of it is cleft into large, rectangular

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blocks by weathering along joint planes and bed planes in such a manner that it is not always very obvious which set of planes represents the dip except as this is indicated by underlying strata. It is impossible to say what thickness it may have had here formerly, as an unknown part of it has been removed by erosion.

At its base in the Trio the Kappa limestone presents a zone several feet thick, composed almost wholly of spherical, oval, or somewhat irregular concretions, from 1 to 3 or 4 inches or occasionally more in diameter. They consist of alternating lighter and darker layers, each a few millimeters thick, and sometimes weather uniformly with the matrix, being then seen in section, or are harder than the inclosing rock, when they are weathered out as pebbles, splitting sometimes into hemispheres which show the concentric layers. This is only an exaggerated sort of pisolitic structure. It is probable that this horizon, like others of the Malone formation, is variable, and that pisolitic structure is only locally developed in it. This rock is very probably similar to the pisolitic limestone conglomerate mentioned by Mr. Taff as constituting No. 9 of his Malone Mountain section.[a]

A reconnaissance was made of the western segment (*A*, *B*) of the Malone Hills, consisting chiefly of limestone and gypsum, with sandstone at its western end (as described by Mr. Robert W. Goodell in connection with his section of the Malone Hills)[b] and at least one remnant of conglomerate at its southern border; also of a ridge of quartzitic sandstone, apparently below the adjacent gypsum, and which forms an eastern foothill of Malone Mountain at the southern end of the mountain, and of portions of the eastern slope and summit of the mountain. But as these were for the most part only cursorily examined, and yielded no fossils except at one locality in the eastern slope of the mountain, no attempt will here be made to correlate positively their stratigraphic subdivisions with those observed at and southeast of the Trio.

Provisionally, however, it may be said that if the gypsum near the southwestern base of hill *C* represents the same horizon as the heavy bed that traverses the western segment of the Malone Hills, and if the latter is but a reappearance of the great gypsum bed the upper limit of whose outcrop disappears by descending northerly from the southern east front of Malone Mountain, then the following inferences would apparently be reached:

(1) That the same gypsum, though not exposed there, probably underlies the highly fossiliferous sandstones and limestones of the Theta at the east end of the Trio and at the Truncate mound.

(2) That the well-stratified limestones and the massive remnant of conglomerate lying above this gypsum and bordering it on the south

[a] Second Ann. Rept. Geol. Survey Texas, pp. 722, 723. [b] Jour. Geol., vol. 5, p. 817.

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in the western segment of the Malone Hills would represent the Theta and the Iota in that quarter.

(3) That the conglomerates above the gypsum in the east face of Malone Mountain, at the southern end of the mountain and at the transverse anticline a mile farther north, would represent, in part at least, the Iota.

(4) That the Theta in the eastern slope of the mountain at its southern end would, if present, belong about at the summit of the gypsum, and that it either has been removed by erosion during the formation of the conglomerates or is possibly represented there by the upper part of the gypsum itself.

The fossils obtained by me from the eastern slope of the mountain were found in a ravine at the base of the mountain, in a horizon of impure limestone, at the passage from conglomerates like those of the Iota to limestones like those of the Kappa, forming part of an obliquely transverse anticline about a mile north of the southern end of the mountain; those collected at the latter locality by Doctor Stanton were obtained in part from limestones somewhat higher in the anticline.

## DISTRIBUTION OF FOSSILS IN MALONE DISTRICT.

A large number of the fossils herein described will be found recorded as having been collected by Doctor Stanton at a number of points on or near Malone Mountain, especially on the western slope and foothills. The great majority of these had previously been found at the notable locality east of Malone, but several will be found listed from the mountain or its western foothills only. Among these are the Nautilus, a few other Mollusca, and the two echinoderms.

How prolific the Malone formation is in fossils at the several collecting stations, and how much the original Malone Hills locality excels the others, may be seen by the following lists:

### OCCURRENCE OF SPECIES BY LOCALITIES.

LOCALITY NO. 1.—*Theta subdivision of the Trio section in the Malone Hills, 1¼ miles east of Malone railway station.*

Astrocœnia maloniana.
Serpula gordialis.
Serpula sp. (large).
Serpula sp. (small, with annular, filiform costellæ).
Berenicea maloniana.
Ostrea sp.
Gryphæa mexicana.
Exogyra subplicifera.
Plicatula sportella.
Lima (Radula) interlineata.
Lima (Ctenostreon) riograndensis.
Pecten insutus.
Gervillia corrugata.
Mytilus nuntius.
Modiola maloniana.
Pinna quadrifrons.
Arca? dumbli.

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Arca taffii.
Cucullæa catorcensis.
Cucullæa texticostata.
Cucullæa transpecosensis.
Leda? navicula?.
Trigonia calderoni.
Trigonia conferticostata.
Trigonia goodellii.
Trigonia munita.
Trigonia proscabra.
Trigonia rudicostata.
Trigonia vyschetzkii.
Astarte? craticula.
Astarte? isodontoides.
Astarte malonensis.
Astarte microphyes.
Astarte posticalva.
Ptychomya stantoni.
Lucina? mexicana.
Lucina potosina.
Lucina potosina, var. metrica.
Unicardium semirotundum.
Unicardium transversum.
Cyprina coteroi.
Cyprina? streeruvitzii.
Tapes? cuneovatus.
Pholadomya marcoui.
Pholadomya paucicosta.
Pholadomya præposita.
Pholadomya tosta.
Pleuromya inconstans.
Pleuromya inconstans, var. curta.
Anatina obliquiplicata.
Anatina pliculifera.
Thracia? maloniana.
Martesia? maloniana.
Pleurotomaria circumtrunca.
Turbo? beneclathratus.
Delphinula stantoni.
Nerita nodilirata.
Nerita peroblata.
Vermetus cornejoi.
Natica bilabiata.
Natica inflecta.
Natica williamsi.
Chemnitzia goodellii.
Nerinea circumvoluta.
Nerinea goodellii.
Nerinella stantoni.
Cerithium arculiferum.
Actæonina? maloniana.
Oppelia? fallax.
Olcostephanus malonianus.
Perisphinctes felixi.
Perisphinctes potosinus.
Perisphinctes schucherti?.
Aspidoceras alamitocensis.
Pycnodont fish tooth.
Cycloid fish scales.
Enaliosaur (fragments of bones, indicating animal of considerable size).

LOCALITY No. 2.—*South border of flat saddle, west of the Trio, about a mile east of the Malone railway station.*

Trigonia vyschetzkii.
Astarte malonensis.
Pleuromya inconstans?.

LOCALITY No. 3.—*Anticline in east slope of Malone Mountain, about a mile north of the southern end.*

Holectypus? sp.
Serpula gordialis.
Gryphæa mexicana.
Exogyra subplicifera (probable casts of).
Modiola maloniana.
Cucullæa catorcensis.
Leda? navicula.
Astarte malonensis.
Unicardium semirotundum.
Unicardium transversum.
Pleuromya inconstans.
Martesia maloniana.
Turritella burkarti.
Chemnitzia goodellii?.
Nerinella stantoni.
Selachian (fin spine of indeterminate genus).



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LOCALITY No. 4.—*About a mile[a] east of the railway station of Finlay; apparently about the same horizon as the locality next below mentioned.*

Gryphæa mexicana.
Lima interlineata.
Pecten insutus.
Modiola geniculata.
Modiola maloniana.
Trigonia calderoni.
Trigonia proscabra?.[b]
Astarte malonensis.
Unicardium transversum.
Chemnitzia goodellii.
Nerinella stantoni.

LOCALITY No. 5.—*Foothills near the railroad, at northwestern end of Malone Mountain, a little over 2 miles east-southeast of Finlay station, not more than 200 feet above the gypsum bed; total exposure above gypsum bed here 540 feet; fossils all from middle hundred feet.*

Cucullæa castilloi.
Lucina potosina, var. metrica.
Lucina planiuscula.
Unicardium semirotundum.
Pholadomya paucicosta.
Nerita finlayensis.
Natica finlayensis.
Natica inflecta.
Nautilus naufragus.
Oppelia fallax?.
Perisphinctes schucherti.

LOCALITY No. 6.—*First high ridge west of Malone Mountain, about 2 miles west of Malone station, in No. 13 of Doctor Stanton's Malone Mountain section.*

Gryphæa mexicana.
Pecten insutus.
Trigonia munita.
Astarte malonensis.
Pleuromya inconstans.

LOCALITY No. 7.—*West of the north part of Malone Mountain, about 2 miles southwest of Malone station, in No. 13 of Doctor Stanton's Malone Mountain section.*

Gryphæa mexicana.
Pecten insutus.
Astarte malonensis.
Unicardium semirotundum.
Pleuromya inconstans.
Martesia maloniana.
Chemnitzia goodellii.
Nerinella stantoni.
Nautilus burkarti?.
Perisphinctes clarki.

LOCALITY No. 8.—*At same locality as the preceding, but from a horizon 220 feet higher, viz, No. 25 of Doctor Stanton's Malone Mountain section.*

Pygurus sp.
Gryphæa mexicana.
Pinna quadrifrons.
Pleuromya inconstans.

LOCALITY No. 9.—*West base of Malone Mountain, a short distance north of the southern end.*[c]

Gryphæa mexicana.
Exogyra potosina (broadly triangular phase).
Gervillia cinderella.
Gervillia? riograndensis.
Pinna quadrifrons.
Pholadomya cf. marcoui.
Pleuromya inconstans.
Pleuromya inconstans, var. curta.
Corbula? maloniana.

[a] Something more than this distance, a little south of east.

[b] A cast; it may possibly represent *T. praestriata.*

[c] On this collecting station, having previously referred in his field notes to a fresh-water limestone 75 to 100 feet below a quartzitic conglomerate at top of Malone Mountain a short distance north of its southern end, Doctor Stanton comments as follows: "In the field this was believed to be between the fresh-water horizon and the quartzitic conglomerate above mentioned. It is certainly several hundred feet above a horizon of the *Gryphæ mexicana* and Nerinea."

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LOCALITY No. 10.—*Foothill west of Malone Mountain, about 2 miles north of its southern end; possibly same horizon as that of the preceding locality.*

Gryphæa mexicana.
Exogyra potosina (narrower phase).
Pecten insutus.
Pinna quadrifrons.
Astarte malonensis?.
Lucina potosina, var. metrica.
Pleuromya inconstans.
Perisphinctes aguileral.

LOCALITY No. 11.—*Near southern end of Malone Mountain, west face, near top; stratigraphic relation obscure.*

Trigonia munita.
Nerinea goodelli.

LOCALITY No. 12.—*Conglomerate on west face and near top of Malone Mountain.*

Trigonia goodelli? (cast, larger than other specimens of this sp.)

LOCALITY No. 13.—*East slope of Malone Mountain near the southern end; 200 or 300? feet above the gypsum.*

Gryphæa mexicana.
Trigonia præstriata.
Oppelia fallax?.
Perisphinctes clarki.

## AGE OF MALONE FAUNA.

The affinities of its fauna clearly refer the Malone formation to the Jurassic. The only evidence that at first thought might seem discordant is the occurrence of the genus Ptychomya, which, with one or two doubtful exceptions, has not been recorded hitherto from rocks older than the Cretaceous. But when it is remembered that, of the Cretaceous Ptychomyas, only one species occurs later than the Lower Cretaceous (Neocomian and Gault) and that this one, the *Pt. zitteli* of the western Alps, is from the Turonian, no species occurring in the higher (Senonian and Danian) stages of the Cretaceous, the occurrence of one or two species of Ptychomya in the upper part of the Jurassic is only that which it would be reasonable to anticipate. This genus occurs at Chillan, Chile, in rocks of debatable age, and it is thought by Doctor Steinmann to have been derived there possibly from the same bed that yielded his *Trigonia transitoria*, from which *T. vyschetzkii* is scarcely distinguishable. The *T. transitoria* occurs also at Caracoles, Bolivia, where, on the basis of the kind of rock attached to the specimen, Doctor Steinmann supposes it to hail from the Lower Cretaceous; but nearly all of the Mesozoic fossils that he lists from Caracoles he considers Jurassic.

The sections *Undulatæ* and *Costatæ*, to which several of the Malone Trigonias belong, are exclusively Jurassic,[a] and, if we except *Tri-*

[a] By Pictet and Campiche (Pal. Suisse; Terr. Cret. de St. Croix, p. 360. 1866) and Stoliczka (Pal. Indica; Cret. Fauna S. Ind., vol. 3, p. 311. 1871), the section *Undulatæ* is said to include some Cretaceous species, but by later authorities it is cited as exclusively Jurassic. Thus it occurs, according to Zittel's Handbuch (1881–1885) "Nur in Jura;" and according to Steinmann and Döderlein's Elemente (1890), "Oberer Lias—Oberer Malm."

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*gonia præstriata*—represented by a single somewhat imperfect mold—none of the Malone Trigonias agree perfectly with generic sections hitherto known from Cretaceous rocks, exclusively.[a] The genus Trigonia is moreover generally considered one of the best of the Lamellibranch genera for purposes of stratigraphic diagnosis.

But it is to the ammonites that we must look for the strongest evidence of geologic age, these being generally regarded as the most critical of molluscan fossils as guides to stratigraphic correlation. And here, too, the evidence is clearly conclusive of Jurassic age. Though several of the genera are common to the Jurassic and Cretaceous systems, all of the known European analogues in species and subgeneric groups are Jurassic. The ammonitic genus of most frequent occurrence in the Malone is Perisphinctes, which is common to the two systems, but is almost exclusively Jurassic. Of the 366 known species of this genus[b] only four, described by Neumayr and Uhlig from the upper Neocomian of Saltzgitter,[c] are Cretaceous; and these belong to a group which the Perisphinctes species of the Malone formation do not at all approach. On the contrary, the species of Perisphinctes to which those of Malone show the closest affinities are those of the Tithonian.

It should be noted that while some of the molluscan fossils other than ammonites seem to indicate Kimmeridgian, or earlier than Tithonian age, this is more or less offset by the presence of the ordinarily Cretaceous genus Ptychomya.

## LOCALITIES OF RELATED FAUNAS.

The only localities which present rocks known to correspond more or less closely with those of the Malone formation are in Mexico.

In the descriptive part of this paper it is noted that some of the fossils of the Malone formation are identical with some of those of the Alamitos beds, described by Castillo and Aguilera as occurring at the Sierra de Catorce in San Luis Potosi, and that others agree with species described by Doctor Felix from the Cerro de Titania in Oaxaca. The number of forms at present known to be common to the Malone and the Alamitos is so considerable that there can be little doubt that these two names represent approximately the same horizon. The ammonites of the Alamitos, like those of the Malone, are of Titonian affinities.

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[a] Doctor Stanton, however, places *Trigonia proscabra* in the Scabræ, and questions whether *T. calderoni* be not referable to that section also rather than to the Undulatæ.

[b] In the body of his recent Monograph of Perisphinctes, Siemiradzki treats 363 species of this genus. In its supplement, of a large number of additional alleged new species cited as described by De Rias and Tornquist in 1898, he identifies all but three with species previously known, so that the number of species recognized by Siemiradzki in the early part of 1899 was 366.

[c] Ueber Ammoniten aus den Hilsbildungen Norddeutschlands; Paleontographica, Bd. XXVII, 1881.

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The number of fossils known from the Jurassic of the Cerro de Titania is small, but indicates, so far as it goes, a position high in the upper Jurassic series, as shown by Doctor Felix; and it is at least worthy of note that of the few lamellibranchs known from these rocks, *Exogyra subplicifera* and *Gryphæa mexicana* occur also at Malone, *Astarte microphyes* may be the same as *A. brexiacola*, and the large *Trigonia sologureni*, known only from the cast, may yet prove to be identical with the Malone species, *T. ryschetzkii*, when the details of its shell come to light.

Besides the Malone district, the Sierra de Catorce, and the Cerro de Titania, several other localities in Mexico have yielded fossils of the Malone formation. Thus a Perisphinctes, supposed to be related to the European *P. balderus*, is apparently common to the Theta and the Alamitos and is reported from Tutotepec also, in the State of Puebla, by Castillo and Aguilera; and by the same writers *Perisphinctes mazapilensis* and *Haploceras mazapilensis* are recorded from the Alamitos and from the Sierra de Zuloaga, in Zacatecas.

A number of Mexican Jurassic localities besides those here mentioned are given in Aguilera's "Sinopsis de Geología Mexicana;"[a] but these are little known, and at some of them the rocks belong, at least in part, to the lower Jurassic. It is, however, interesting to note that the Jurassic district of Malone is in the continuation of the belt along which are scattered all or nearly all of the Jurassic tracts shown on the geological map of Mexico of 1897 published with Nos. 4–6 of the Boletin del Instituto Geológico de Mexico.

It is not improbable that rocks nearly related to the Malone occur in South America. As shown in the discussion of that species, *Trigonia ryschetzkii* is very close to the Andean form, *T. transitoria* Steinmann, a species whose precise geological position has hitherto been doubtful, but which the evidence from the Malone district tends to show probably belongs to the upper Jurassic.

ACKNOWLEDGMENTS.

I wish to acknowledge my indebtedness to all of those mentioned elsewhere herein as having contributed directly or indirectly to the success of this study. The kind services of the Messrs. Goodell were of especial value, as furnishing the first fairly conclusive indication of the Jurassic age of the Malone formation. To the Hon. Charles D. Walcott, Director of the United States Geological Survey, and to Mr. Charles Schuchert, Curator of Invertebrate Paleontology in the United States National Museum, I am indebted for important aid. I am under obligations also to Mr. John N. Gilcrease, Mr.

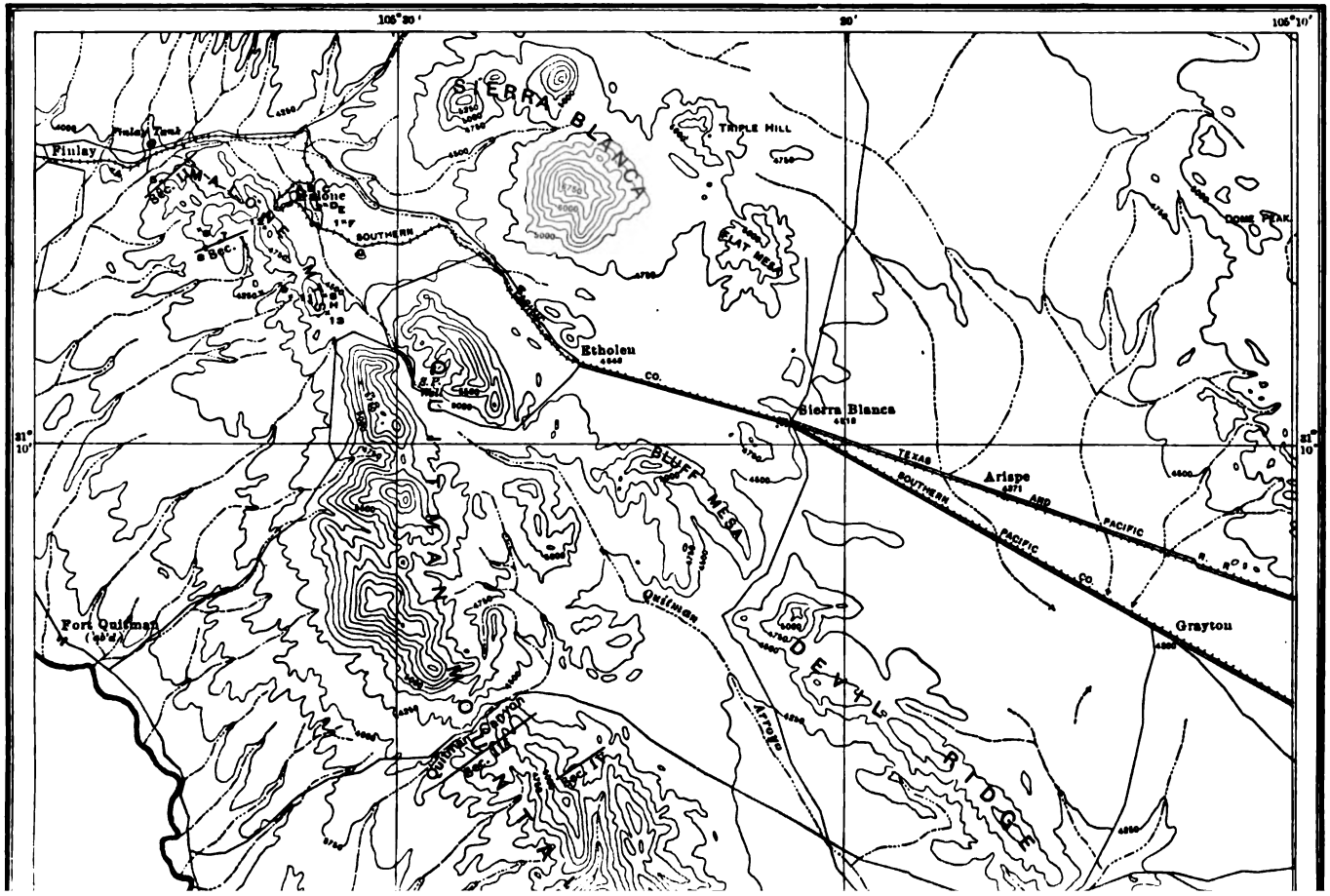
[a] In Bosquejo, Geología de Mexico: Boletin del Instituto Geologico de Mexico, Nos. 4–6, pp. 187–250.

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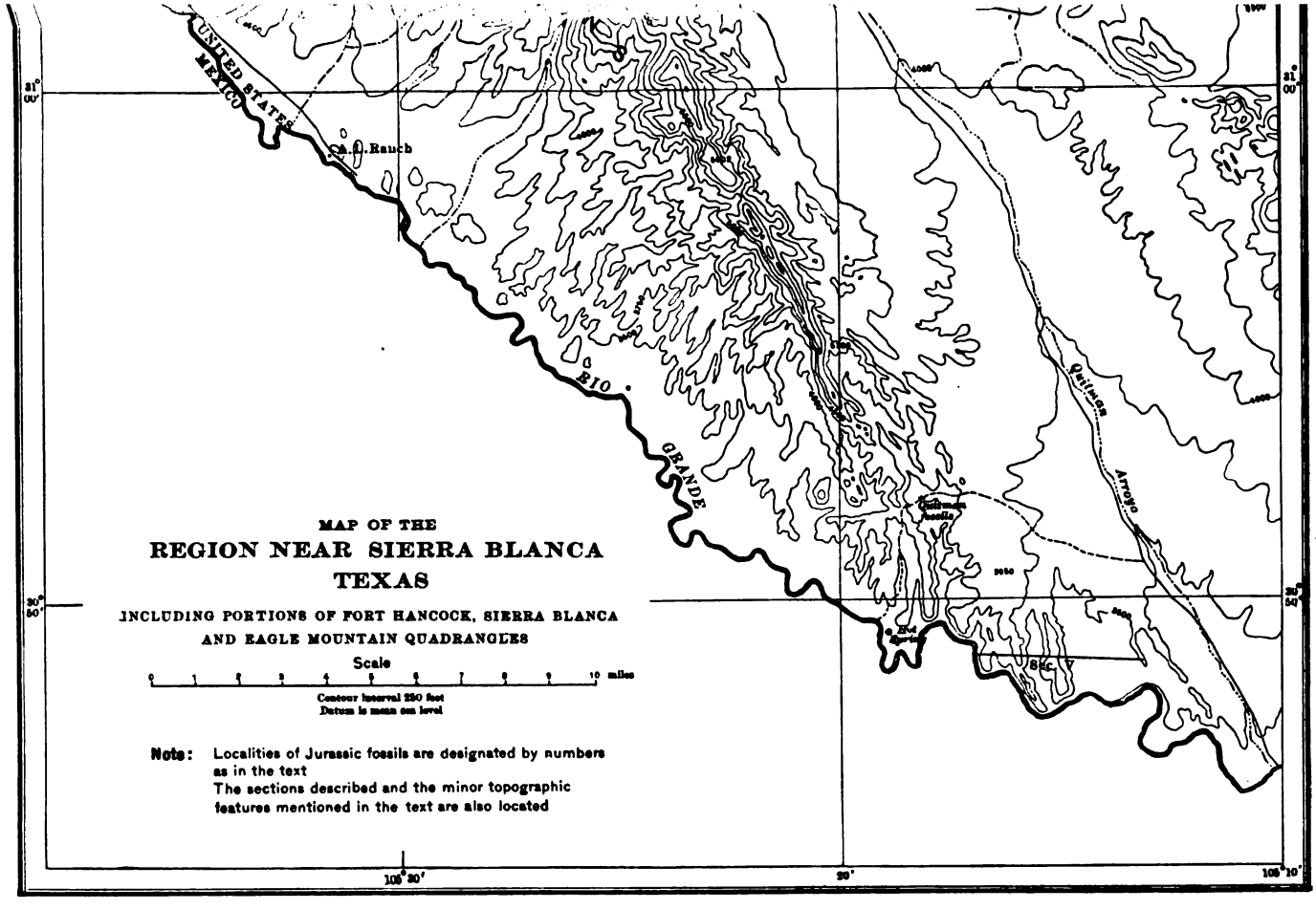
Charles M. Wilson, and Mr. John W. Williams for favors rendered while I made headquarters at Sierra Blanca, and particularly to Mr. Williams, who showed much interest in the Malone investigation, assisted in collecting, and facilitated the field work in every possible way, contributing in no small measure to its success. I deem it but simple justice to Doctor Stanton, and at the same time a pleasure, to state that I owe very much indeed to his full and generous cooperation in promoting every desired use of the collections under his charge, and in holding at my service a splendid knowledge of Mesozoic conchology and its literature and methods. And, finally, it is also due to Prof. William Bullock Clark, head of the geological department of Johns Hopkins University, to add that without his efficient planning of it as a whole, this contribution to American Jurassic paleontology could have been undertaken at this time, if at all, only under far greater limitations, both as to scope and as to facilities for research.

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MAP OF THE

# REGION NEAR SIERRA BLANCA TEXAS

INCLUDING PORTIONS OF FORT HANCOCK, SIERRA BLANCA AND EAGLE MOUNTAIN QUADRANGLES

Scale

0 1 2 3 4 5 6 7 8 9 10 miles

Contour interval 250 feet
Datum is mean sea level

**Note:** Localities of Jurassic fossils are designated by numbers as in the text
The sections described and the minor topographic features mentioned in the text are also located

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# STRATIGRAPHIC NOTES ON MALONE MOUNTAIN AND THE SURROUNDING REGION NEAR SIERRA BLANCA, TEX.

By T. W. STANTON.

## GENERAL REMARKS.

It has been deemed advisable to supplement Professor Cragin's paleontological paper by a brief account of the general geology of the region in which his Jurassic fauna occurs. The data here presented were obtained in 1897 and 1898 during two reconnaissance trips undertaken for the purpose of unraveling the obscure Cretaceous section of the Sierra Blanca region and, if possible, of determining the stratigraphic relations of the Malone Jurassic with the Cretaceous, as well as of making collections from all of the fossiliferous horizons of the region. The stratigraphy of the Cretaceous was determined fairly well, several fossiliferous horizons in the Jurassic of Malone Mountain were established, and interesting collections of fossils were obtained from both the Cretaceous and the Jurassic, but the rocks of the two systems were not found associated in the same continuous section, and their stratigraphic relations were not definitely determined.

In 1897 two weeks were spent at Sierra Blanca station examining the outcrops within a few miles of that station and one excursion was made 25 miles southward, to the Rio Grande. In 1898 a month was spent in the region working with a wagon and camp outfit, but even then many points could not be conveniently reached nor thoroughly studied because, on account of the scarcity of water and of roads, camping places were limited in number. The area examined comprises parts of the Fort Hancock, Sierra Blanca, and Eagle Mountain quadrangles, as mapped by the United States Geological Survey, extending from the Finlay Mountains on the north to the Rio Grande on the south and from the western foothills of Malone and Quitman mountains to Devils Ridge and Eagle Mountain on the east.



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The region as a whole is characterized by rugged hills, ridges, and mountain masses rising abruptly from broad valley plains which are filled to an unknown depth with coarse Tertiary (?) deposits that obscure the structure of the older rocks beneath them. The general strike of the uplifted strata is northwest and almost all the smaller hills and ridges are monoclinal, with beds generally dipping southwest. In describing the Cretaceous deposits of this region in 1891, Mr. J. A. Taff[a] thought that the beds exposed north of the Sierra Blanca station are the oldest and that successively newer beds are found to the southwest except that there is some repetition by faulting. This opinion was based on the general posture and geographic relations of the beds and on the lithologic similarity of certain conglomerates and limestones in the Jurassic and the Cretaceous. The characteristics of the faunas involved were then practically unknown. It will be shown, however, that the real succession of strata is very different from that given in Mr. Taff's published section, the oldest Mesozoic rocks being found in Malone Mountain. Mr. Taff briefly discussed the folding and faulting that is common throughout the region and that is doubtless often present under the débris of the valleys as well as in the mountain masses. It would require much more time and study than has yet been given to this area to work out all its details of structure, which is further complicated by many intrusive masses of igneous rock in all the larger uplifts except Malone Mountain.

## MALONE MOUNTAIN AND THE JURASSIC.

The strata bearing the Jurassic fauna described by Professor Cragin have been found only in Malone Mountain and the adjacent valleys. The Malone Mountain uplift extends from the Southern Pacific Railway near Finlay station about 5 miles in a southeasterly direction and ends abruptly a few hundred yards from the northwesterly extremity of the Quitman Mountains. Malone station, which is 13 miles by rail from Sierra Blanca station, is at its eastern base a little north of the middle. From this direction the mountain looks like a simple unbroken ridge, but on the southwest side it is deeply dissected by both transverse and longitudinal valleys.

The general structure seems to consist of a syncline along or east of the crest of the principal ridge, with an anticline in the valley and subordinate ridges of the west slope. There are also several minor folds, often beautifully shown, and doubtless some faulting. Toward the southern end of the mountain a small anticline is developed on the eastern slope. Mr. Taff has published a figure of the Malone Mountain section[b] showing these general structural features. He has

[a] Second Ann. Rept. Geol. Survey Texas, pp. 714–738. [b] Idem, Pl. XXVII.

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also described[a] the succession of strata in the middle section of the mountain, which agree in the main with my observations, though both structure and exposures vary greatly in different parts of the uplift.

The most complete section that I observed, in which the thicknesses were estimated with some care, extends across the mountain from a point on the east side about one-half mile south of Malone station. The eastern face of the mountain shows an apparent thickness of about 1,200 feet of blue and gray limestones, with a few intercalated beds and bands of conglomerate and sandstone, the beds all dipping strongly westward with increasing dips until they become vertical on the crest. On the west slope there is a succession of limestones, conglomerates, and gypsum beds, nearly vertical and not well exposed, and farther down these are apparently repeated with a westerly dip, overlain by conglomerates, limestones, etc., fairly well exposed and not much disturbed in the lower ridges to the west. The gypsum beds and the limestones immediately associated with them appear to be the oldest rocks exposed. The following section begins with what was supposed to be the lowest gypsum bed, but on account of complex structure and obscure exposures the succession and thickness of the first five members are somewhat uncertain.

*Section of Jurassic beds on west side of Malone Mountain, near Malone station (Section 1 of map).*

| | Feet. |
|---|---|
| 1. Gypsum, not well exposed, about | 100 |
| 2. Calcareous conglomerate, almost vertical | 45 |
| 3. Mostly covered; limestone below, gypsum above (dip variable, westward), about | 200 |
| 4. Altered and fissured limestone | 125 |
| 5. Gypsum, not well exposed | 100 |
| 6. Siliceo-calcareous shale | 40 |
| 7. Limestone | 20 |
| 8. Covered (shale?) | 100 |
| 9. Blue limestone, with traces of fossils | 2 |
| 10. Covered | 15 |
| 11. Arenaceous limestone | 1 |
| 12. Covered | 10 |
| 13. Blue limestone, with the Malone fauna | 2 |
| 14. Covered | 10 |
| 15. Limestone | 1 |
| 16. Covered | 8 |
| 17. Thin-bedded limestone and shales | 20 |
| 18. Calcareous conglomerate | 15 |
| 19. Limestone with Pleuromya and Gryphæa | 15 |
| 20. Covered | 10 |
| 21. Calcareous conglomerate | 15 |

[a] Idem, pp. 722–723.

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| | Feet. |
|---|---|
| 22. Limestone with fragmentary fossils (Ammonites, etc.) | 10 |
| 23. Calcareous conglomerate | 15 |
| 24. Covered | 100 |
| 25. Limestone with Gryphæa, Pinna, Trigonia, etc | 15 |
| 26. Covered in talus slope | 150 |
| 27. Thin-bedded brown sandstone with bands of conglomerate and containing a small Ostrea, Nerinea, and a few other fossils, poorly preserved | 25 |
| 28. Massive, gray, calcareous sandstone | 10 |
| 29. Gray limestone forming a prominent ridge | ±250 |
| 30. Brown conglomerate, composed mostly of quartzite and chert pebbles | 40 |
| 31. Blue limestone | 100 |

This is uncomformably overlain by the unconsolidated Tertiary or Pleistocene conglomerates of the plains on the west.

The main ridge of Malone Mountain on the line of this section seems to be made up of Nos. 29, 30, and 31, with perhaps some higher beds, all repeated by the synclinal fold.

Nos. 13 and 25 each yielded fossils, some of which are specifically identical with forms occurring at Professor Cragin's principal locality for the Malone Jurassic fauna, and the fossils mentioned in other bands (Nos. 9, 19, 22, and 27) evidently belong to the same fauna.

Some bands in the limestone No. 29 yielded a few fossils that seem to be fresh-water forms—small, simple gasteropods, resembling Viviparus. Similar forms were seen in No. 31 also.

Near the south end of Malone Mountain the same horizon in No. 29 yielded some small bivalves with the external features of Unio associated with the gasteropods. Conglomerate No. 30 of the section, however, contains marine fossils, including Ammonites, Exogyra, and several other genera. These were not found on the line of the section above described, but the conglomerate is a prominent, easily recognized horizon exposed at many points along the entire length of the mountain, and the fossils, usually in the form of imprints and fragments, were seen at several places both north and south of the section, especially toward the southern end of the mountain. In the western foothills of the mountain, 1 to 2 miles north of the southern end, there are exposures of a conglomerate believed to be the same as No. 30, and in the uppermost bands of the limestone immediately beneath it collections were obtained containing Exogyra, Pinna, Pecten, Pleuromya, Perisphinctes, etc., which Professor Cragin has assigned to the Malone fauna (see p. 19).

At the end of the northwest spur of Malone Mountain, at the point where it approaches the railroad, there are large exposures of gypsum that almost certainly belong to the gypsiferous horizons in the section just described, though they are separated from them by struc-

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tural breaks.[a] In the following section the estimated thicknesses of the gypsum and the beds overlying are not closely accurate, because the exposures are very incomplete and the dips are variable and not easily determined.

*Section near northwest end of Malone Mountain about 2 miles southeast of Finlay station (Section II of map).*

| | Feet. |
|---|---|
| 1. Gypsum | 100 or more. |
| 2. Mostly covered about | 200 |
| 3. Limestones with conglomerate layers alternating with softer shaly bands. Several fossiliferous horizons with Malone fauna (see lists, p. 18) | 75 |
| 4. Limestones passing into calcareous conglomerate | 15 |
| 5. Limestone with a few Malone fossils | 15 |
| 6. Calcareous conglomerate | 6 |
| 7. Covered (shales and limestone) | 20 |
| 8. Calcareous conglomerate | 10 |
| 9. Blue limestone dipping 20° SW., with echinoids and large Nerinea seen in section on weathered surface | 6 |
| 10. Blue limestone and shale passing under the plain | 200 |

There can be little doubt that the fossiliferous beds in this section are on very nearly the same horizons as those in the section west of Malone station.

The most prolific locality for Malone Jurassic fossils, and the only one not directly connected with the mountain itself, is in the low hills in the valley about 1½ miles east of Malone station. The exposures are comparatively small and the dips variable, so that the stratigraphic details either as to thickness or succession can not be determined with certainty. Professor Cragin gives his observations on this locality fully in another place (pp. 13–17).

It is not possible to make a definite correlation of the fossiliferous beds here with any single horizon in the Malone Mountain sections, but it is most probable that they belong not more than 300 feet above the main gypsum beds.

At this point the Malone Jurassic beds are closer to fossiliferous Cretaceous beds of determined horizon than at any other place observed in the region. About 3 miles to the east, near the southwest base of Sierra Blanca, there are exposures of Washita beds with *Nodosaria texana* and *Gryphæa mucronata* (?), and the same horizon occurs a little farther away along the railroad between Etholen Hills and Quitman Mountains.

Mr. Taff correlated portions of the Malone Mountain section with exposures in the conical hills near Etholen about 5 miles west of

[a] Mr. Taff assigned these gypsum exposures, as well as those at the southeast end of the mountain, to a higher horizon (see pp. 725 and 736 of his report), but they all have the same relations to the fossiliferous horizon bearing the Malone fauna.

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Sierra Blanca station, and in Bluff and Yucca mesas near the same station, but I was unable to confirm these correlations. The strata in the "Etholen Knobs" may possibly belong here, but the other localities almost certainly show only Cretaceous beds.

## THE CRETACEOUS.

Cretaceous rocks have a great development in this region and represent the three main divisions of the Comanche series—the Trinity, Fredericksburg, and Washita—as well as a part of the Upper Cretaceous. Lithologically the section differs greatly from that of Central Texas, where the Comanche series has been most studied, and there are also considerable differences in the vertical range of some of the common species, so that it is impracticable to recognize many of the minor formations and horizons that have been studied. The general faunal succession is the same in both regions, and it is usually not difficult to classify the beds by means of the fossils as Trinity, Fredericksburg, or Washita, though it was difficult and sometimes impossible to assign each exposure to its exact position in the general section, because many of them are relatively small and isolated, and the structure is complicated by folds, faults, and igneous intrusions. The most complete sections are to be found in the Quitman Mountains, especially toward the southern end and in the lower hills farther south on the Rio Grande, in the southern extension of the same line of uplift.

*Quitman Mountains.*—This range begins at a point on the railroad 8 miles west of Sierra Blanca station and extends in a southeasterly direction about 25 miles, the uplifted beds continuing as low ridges in the same direction and crossing the Rio Grande 6 or 7 miles beyond the end of the main range. At its northern end it is composed mainly of igneous rocks—granites and porphyries—with Cretaceous beds in the adjacent foothills on the north and east, but south of Quitman Canyon, a drainage channel that cuts straight across the range about 10 miles south of its northern end, the mountain mass is composed of Cretaceous sediments, with only occasional igneous intrusions. The axis of the range is for a number of miles almost parallel with the Rio Grande, which flows about 6 miles to the southwest, while on the other side is the flat valley of Quitman Arroyo, 4 to 10 miles wide, separating the Quitman Mountains from Devils Ridge and Eagle Mountains. Sections taken at different points across this range vary greatly in extent. The one published by Taff in the report cited was taken near Quitman Canyon (Section III of map), and shows the strata with variable steep dips mostly to the west, but sometimes reversed. Near the eastern end of the section is a heavy bed of limestone, forming part of Taff's "Bluff bed," filled with *Orbitolina texana* and a

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few other forms, followed by a band of hard limestone containing numerous specimens of Requienia. Then comes the "Quitman bed," composed of sandstones, clays, and thin beds of limestone, with a thickness of 330 feet, succeeded on the west by a great series of sandstones and siliceous limestones, the "Mountain bed," with an apparent thickness of about 4,000 feet. The western end of the section was thought to be the top, and the entire section was referred to the Washita division of the Comanche series. My studies of more complete sections farther south in the same range, especially the one near the Rio Grande, led to the conclusion that the beds at Quitman Canyon and for a long distance southward are mostly overturned, and that the oldest rocks are on the west side of the mountains.

The Mountain bed, consisting mostly of coarse, varicolored sandstones, forms the western portion of the mountain all the way to the Rio Grande at Hot Springs, where it dips to the east instead of to the west. Its apparent great thickness may be due in part to folding and faulting. It has yielded only imperfectly preserved Ostrea and a few other forms that are insufficient for its correlation with established formations.

The Quitman bed has a similar distribution along the higher (western) slope of Quitman Mountain. Its fauna shows a different facies from any assemblage in the Central Texan section, including *Exogyra quitmanensis*, *Trigonia taffi*, *Trigonia stolleyi* (?), *Remondia*, and a considerable number of forms that will be described in a monograph of the Comanche fauna. Although some of the species show relationship with later faunas the stratigraphic and paleontologic evidence as a whole is thought to justify its assignment to the Trinity division. The best localities found for collecting this fauna are on Quitman Mountain about 1 mile south of Quitman Canyon, and on the trail from Quitman Arroyo to Hot Springs, about 3¼ miles from the springs.

The Orbitolina limestone for many miles forms the crest of the Quitman Mountains, with a bold escarpment on the east and a steep slope corresponding with the dip on the west. Its characteristic foraminifera, *Orbitolina texana* (Roemer), occurs only in the Glen Rose beds of the Trinity division in Central Texas. Another species of the same horizon that occurs with it in the Quitman Mountains is the large *Natica prægrandis* Roemer, which is usually treated as a synonym of *N. pedernalis*. The Orbitolina limestone has here a thickness of at least 250 feet, and farther south on the Rio Grande it appears to be still thicker, and the Orbitolina again appears in a thinner limestone about 300 feet higher.

On the eastern slope of the mountain 1 to 2 miles south of Quitman Canyon there are exposures of several hundred feet of limestones, clays, and sandstones dipping toward the mountain and apparently

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underlying the Orbitolina limestone (Section IV of map). The succession from the Orbitolina limestone eastward down the mountain is as follows:

| | Feet. |
|---|---|
| 1. Alternating thin beds of sandstone and clay, with occasional bands of limestone; *Exogyra texana* near the middle | 200 |
| 2. Alternations of limestone and covered spaces | 200 |
| 3. Sandstone | 8 |
| 4. Covered | 15 |
| 5. Sandstone with *Actæonella dolium* | 15 |
| 6. Argillaceous limestones, clays, and some arenaceous bands, with occasional layers containing *Exogyra texana* | 300 |
| 7. Limestone in several massive beds interstratified with more or less argillaceous nodular beds; some of the harder bands full of *Caprina occidentalis* Conrad | 75 |

Farther east some of these beds are repeated, dipping eastward. It is evident that these beds are in part the equivalent of those described by Taff as occurring in Flat Mesa, 4 miles north of Sierra Blanca, and that they should be included in the Fredericksburg division.

About 10 miles south of Quitman Canyon and less than 2 miles south of the northern boundary of the Eagle Mountain quadrangle the east face of the mountain shows a similar section, and at its base there are small exposures of Washita beds with *Schlœnbachia vespertina* and a few other forms, dipping toward the mountain and thus giving additional evidence of overturning and faulting.

*The Rio Grande section.*—Still farther south, near the Rio Grande, the upper part of the section is much more complete and more simple, furnishing the key to the sections already discussed, which are parallel with it across the same line of uplift. The eastern end of the section is about 1 mile north of the Rio Grande in the first hills west of the board valley of Quitman Arroyo. Here the beds are sharply folded and a prominent ridge shows an anticline consisting of argillaceous limestone belonging to the Washita division.

The western limb of the anticline dips 70° to 80° west, and the exposure is as follows:

*Section in hills just west of Quitman Arroyo, about 1 mile north of the Rio Grande (Section V of map).*

| | Feet. |
|---|---|
| 1. Argillaceous limestone, weathering in nodular form, with bands of harder limestone | 200 |
| 2. More massive limestone, much seamed and fissured | 30 |
| 3. Dark, fissile shale, with occasional bands of impure brown limestone, underlying a valley about 1 mile wide. Dips at first steep to the west, becoming variable and much less toward the middle of the valley and again steep to the west on the west side of the valley. *Inoceramus labiatus* and a few other Upper Cretaceous fossils were found west of the middle of the valley; thickness apparently several thousand feet. | |

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| | Feet. |
|---|---|
| 4. Massive limestone, probably same as No. 2 | 30 |
| 5. Argillaceous limestone with some bands of clay and sandstone; fossils: *Nodosaria texana*, *Enallaster texanus*, *Neithea texana*, *Exogyra arietina*, *E. drakei* var., *Plicatula incongrua*, and other Washita forms | 300 |
| 6. Heavy-bedded limestone (40 feet) forming a cliff, followed by argillaceous nodular limestone (30 feet), which yielded *Enallaster texanus*, *Gryphæa corrugata*, *Lima wacoensis*, *Neithea texana*, and *Schlœnbachia vespertina* | 70 |
| 7. Similar limestones with dip not less than 45° westward | 300 |
| 8. More argillaceous light-gray limestone, interstratified with dark clay shales; one of the limestone bands yielded *Epiaster whitei*, *Terebratula* (*Kingena*) *wacoensis*, *Gryphæa washitaensis* (?), *Plicatula incongrua*, and *Schlœnbachia vespertina*, and another band farther west yielded *Epiaster whitei*, *Schlœnbachia acutocarinata*, *S. serratescens*, and *Hamites fremonti* | 300 |
| 9. Dark clays with brownish calcareous bands; *Exogyra texana* abundant | 50 |
| 10. Covered | 100 |
| 11. Limestone, very heavy-bedded above, with increasing bands of argillaceous limestone below; Requienia and a small conical Foraminifera abundant; *Exogyra texana* also occurs | 300 |
| 12. Shales, limestones, and bands of brown sandstone, not well exposed | 250 |
| 13. Argillaceous limestone, with some harder bands containing "Caprina" and Requenia | 75 |
| 14. Generally more massive limestone with some bands of brown sandstone. Also contains "Caprina," Ostrea, etc | 350 |
| 15. Quartzitic sandstone with thinner bands of clay shale and impure limestone, dipping steeply westward | 400 |
| 16. Hard, blue limestone, full of *Orbitolina texana* | 60 |
| 17. Sandstone and impure limestone with some clay | 40 |
| 18. Sandstones and clays | 250 |
| 19. Thin-bedded passing into massive limestone, full of *Orbitolina texana*; at least | 300 |

The steep western surface of No. 19 forms the eastern wall of the canyon of the Rio Grande at this point.

So far there has been no apparent serious break in the section, but the beds now become complexly faulted and folded. A short distance north No. 19 is cut off by a fault, and on the west, across the river, the same bed seems to be repeated in several postures.

It is evident that the eastern portion of the section crosses a syncline, so that in passing from No. 1 to No. 5 the same beds are all crossed twice. In the rest of the section, while there may be some repetition of beds due to small faults, there are no anticlines nor synclines, and the fossils show that in general the beds are successively older toward the west. No. 3 is Upper Cretaceous, of the age of the Fort Benton; Nos. 4 to 8 are Washita; Nos. 9 to 14, and probably 15, are Fredericksburg; and Nos. 16 to 19 belong to the Trinity. As the dips are all steep to the west it follows that all the

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beds from No. 4 to No. 19, inclusive, are overturned. It will be seen also that the succession of rocks and fossils is similar to that found on the east slope of the mountains near Quitman Canyon, and that there is no place for the great sandstone series of the "Mountain bed" within the Washita division. It must be older than the Orbitolina limestone.

*Eagle Mountains.*—These mountains, which lie 10 miles east of the southern end of Quitman Mountain, are composed mostly of igneous rocks, but sediments are exposed on their flanks. My examinations were along only the western base, where there are some exposures of Fredericksburg limestone and shales and apparently some Trinity limestones. Mr. Taff reports Upper Cretaceous and the Orbitolina limestone on the other side of the mountains, and fossils in the collection of Prof. W. F. Cummins, at Dallas, indicate the presence of upper Washita beds "1 mile north of gap in Eagle Mountains."

*Sierra Blanca.*—This group of conical peaks, about 6 miles northwest of the railroad station of the same name, is also composed of igneous rocks with Cretaceous sediments around the base. On the southwest side of the main peak there are fossiliferous exposures of Fredericksburg age noteworthy for containing *Exogyra texana* and *Nodosaria texana* in the same bed. The same association is found in the Finlay Mountains also. Beds of about the same age with *E. texana* and *Actæonella dolium* occur in Flat Mesa, about 4 miles east.

In the saddle between the main peak and the north peak of Sierra Blanca there are considerable exposures of very fossiliferous Washita beds with many characteristic species.

*Finlay Mountains.*—These hills begin about 4 miles north of the north end of Malone Mountain and 6 miles northwest of the main peak of Sierra Blanca and extend several miles to the north and northwest. They were rather hastily examined in the hope of finding an extension of the Malone beds, but the only fossiliferous beds seen belong to the Fredericksburg division of the Cretaceous, including the horizon of *Actæonella dolium.* There are many intrusive masses of igneous rocks and at one locality a considerable development of a coarse calcareous conglomerate whose relations were not definitely determined, though it seemed to belong to the Cretaceous.

*Other localities.*—Other exposures in the neighborhood of Sierra Blanca station were examined, especially Bluff Mesa and Devils Ridge, without very definite paleontological results. The top of Bluff Mesa, 3 miles southwest of Sierra Blanca, is composed of Orbitolina limestone, and it is probable that the underlying beds belong within the Trinity division.

The Orbitolina limestone, the Quitman bed, and a considerable thickness of Fredericksburg beds are well exposed in the neighbor-

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hood of the abandoned "A L Ranch" on the Rio Grande west of Quitman Mountains, in the small triangular area bounded by the river and the Eagle Mountain and Fort Hancock quadrangles. The Fredericksburg beds are especially well exposed about 2 miles down the river from the ranch, in the small canyon locally known as the "Cajoncito." The next prominent ridge, 3 or 4 miles to the east, shows Washita shales and limestones, with intervening dark shales that may belong to the Upper Cretaceous.

These details of the stratigraphy and distribution of the Cretaceous in this region are given for the purpose of emphasizing the peculiarities and the isolation of the Malone beds.



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# DESCRIPTIONS OF THE SPECIES.

## CŒLENTERATA.

### ANTHOZOA.

Several coralla of the massive shape and a segment of a digitiform branch, which in my preliminary manuscript on the Malone fauna I had described as two species of Astrocœnia, were eventually submitted to Mr. T. Wayland Vaughan, who is engaged in a special study of the Neozoic corals, for more detailed study than I could give them. Of these, Mr. Vaughan has very kindly furnished the following description:

Genus ASTROCŒNIA M. Edwards and Haime.

ASTROCŒNIA MALONIANA sp. n.

Pl. II, figs. 1–3.

"Professor Cragin has submitted to me for study and description 9 specimens of an Astrocœnia collected by him 1½ miles east of Malone, Tex. The original substance of the skeleton has been transformed in the process of fossilization into a bluish limestone; the skeletal elements are now represented by crystalline calcite and the interspaces are filled by the same mineral. The result of these chemical changes is to make a study of the thin sections of the specimens very unsatisfactory. No minute structural features could be deciphered, and very often even the grosser ones of the individual corallites are obliterated or can be discovered only with difficulty.

"Apparently only one species is represented in the collection, but there is a central or type form around which the other specimens can be grouped. The type form will be described first.

"The corallum is a gibbous mass, with a flat base having a rather large surface; the upper surface is rather uniformly rounded or thrown into numerous mammillæ. The intergradation between these two types of upper surface can be seen in the specimens before me. When the mammillate character has reached its maximum development the external appearance of the corallum is identical with that of the common recent West Indian *Porites astreoides* Lamarck. The dimensions of two large specimens, both of which possess the mammillate upper surface, are:

| | mm. | mm. |
|---|---|---|
| Greatest breadth | 113 | 96 |
| Least breadth | 95 | 82 |
| Height | 52 | 56 |



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"The above represents the type form of the corrallum. There is one specimen, with a mammillate surface, which shows no place for attachment, and other specimens show a tendency to form low columns.

"The corallites are polygonal, usually hexagonal, are crowded together, and are joined by their directly fused walls. The wall between adjoining corallites is usually thin, but in some instances it may be rather thick, in extreme cases almost 1 mm. When the wall is thin, its upper edge is acute; when it is thick, it is flattened between adjoining calices. The depth of the calicular cavity is so variable that it possesses no value in the specific diagnosis; it is sometimes deep and sometimes very shallow in the same colony. The diameter of the calices vary in the same colony from 1.5 to 2.5 mm. The minimum diameter for a calice is 1 mm. and the maximum is about 3 mm., or a very little less. The number of septa is 16 or 20. There are either 8 or 10 principal septa, with smaller ones between. At their margins the septa are usually rather thin, but deeper down in the corallite are secondarily thickened. The septa are thicker peripherally at the wall and are also thickened around the columella. The septa of adjoining corallites meet end to end or alternate with each other. In transverse sections of corallites dissepiments are very rarely present. No further information can be given concerning the endotheca. The columella is small, low, weak, and styliform. Below the bottom of the calice it is strengthened by having the thickened inner terminations of the principal septa fuse around it. Gemmation takes place in the angle between adjoining corallites.

"There is another specimen not included in the above. It is an Astrocœnia, apparently growing in digitate branches. There is not enough material to warrant naming and describing it."

# ECHINODERMATA.

## ECHINOIDEA.

### HOLECTYPOIDA.

#### Genus HOLECTYPUS Desor.

HOLECTYPUS? sp.

An echinoid fragment indicating a test shaped as in this genus, but with the details too poorly preserved to allow a satisfactory description or an absolute generic identification, was obtained by Doctor Stanton from an anticline on the east slope of Malone Mountain, about 1 mile north of the southern end.

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## SPATANGOIDA.

### Genus PYGURUS Agassiz.

#### PYGURUS sp.

Among the specimens submitted by Doctor Stanton is a fragment of the test of a sea-urchin of the genus Pygurus. It includes the main part of the aboral half of an ambulacrum. The genus is clearly determined by the form of the ambulacrum and the form and arrangement of the pores, as well as by the character of the tubercles and by the discoidal form of the test, the latter form being indicated by the flatness of the part preserved. The ambulacrum has the biconcave outline that characterizes the upper part of that of Pygurus. The pores of the outer row are very long and slit-like, widened slightly toward the outer end, and subhorizontal to more or less oblique; those of the inner row more ringent, compressed dot-like or hyphen-like, and oblique, their width being considerably less and their length considerably more than that of any of the circumtubercular courts on the neighboring part of the ambulacrum. The ambulacral plates are exceedingly narrow; the imperforate part of each, in the widest part of the ambulacrum, being about ten times as long (transverse) as wide (parallel to the course of the ambulacrum) and ornamented with 1 to 3 small perforated tubercles, each of which is set in a round, depressed court. The distribution of these tubercles is irregular, but they are so few and so feebly developed on the inner ends of the plates as to give the ambulacrum the aspect of having a median plain zone, to which the seams between the plates give a transversely striated appearance.

*Measurements.*—Maximum width of ambulacrum 16, of which the two pore belts each occupy 3.5 and the imperforate tract 9 mm.; length and width of imperforate part of an ambulacral plate in broadest part of ambulacrum, respectively, 4.5 and 0.43 mm.; length of outer slit-like pores in broadest part of ambulacrum 2 mm., which is about one-fourth of the width of a semiambulacrum.

*Occurrence.*—West side of Malone Mountain, about 2 miles southwest of Malone station, in No. 25 of Doctor Stanton's Malone Mountain section; with *Gryphæa mexicana*, *Pleuromya inconstans*, *Pinna quadrifrons*, etc.

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# VERMES.

## ANNELIDA.

### TUBICOLA.

#### Genus SERPULA Linnæus.

SERPULA GORDIALIS Schlotheim.

Pl. II, figs. 5–6.

A round-tubed, nearly smooth, irregularly constricted, at first spirally coiled, then contorted Serpula, probably the same as that noted by Doctor Felix[a] from the upper Jurassic rocks of the Cerro de Titania in the State of Oaxaca, Mexico, and referred by him to Schlotheim's *S. gordialis*, is the commonest tubicolan of the Malone fauna, having been found at the anticline in the eastern base of Malone Mountain (in both Doctor Stanton's collections and mine), and at the locality 1½ miles east of Malone station. The largest tubes observed measure about 2.7 mm. in diameter, 1 to 2 mm. being a more common size.

SERPULA sp.

Pl. II, fig. 4.

Not rare at the locality last mentioned is a large Serpula, apparently differing from *S. gordialis* chiefly in size, but perhaps also having a less constantly or less intricately contorted habit. As there found, it attains a diameter of at least 8 mm.

SERPULA sp.

A single specimen of a third and well-marked species of Serpula was obtained from the same locality, but was lost in the laboratory when it had received only preliminary study. The following are its characters so far as they were noted:

Tube considerably smaller than an average one of *Serpula gordialis*, straight, round, and at least in part terete, its exterior ornamented with close, uniform or nearly uniform, prominent, filiform, encircling costellæ, so that its appearance recalls one of the smaller of the wound wires in the lower register of a piano; an ornamentation which contrasts strikingly with the plain to feebly and irregularly constricted exterior of the two other known Serpulæ of this district.

[a] Beiträge Geol. u. Pal. Mex., pt. 3, p. 175. Palaeontographica, vol. 37. 1891.

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# MOLLUSCOIDEA.

## BRYOZOA.

### DIASTOPORIDÆ.

Genus BERENICEA Lamouroux.

BERENICEA MALONIANA sp. n.

Pl. II, fig. 7.

Colonies incrusting, sometimes confluently associated, unsymmetrically flabelliform, apparently without a tattered or incised border; cells numerous, several hundred in a colony, tubular, arising as if separately in quincunx-radial order from the smooth or finely porous membrane-like stock which separates them by intervals for the most part about equal to themselves, the lower part of each cell being embedded and subhorizontal, the outer part rising obliquely and becoming gradually free or nearly so, being wholly free at the very extremity only; free surface of cells plain or at most only finely striate; oral extremity contracted, the aperture small and round.

*Measurements.*—Breadth of colony, 12 mm.; of cell, 0.2 mm.; of oral aperture, about 0.1 mm.; greatest exposed length of cells between twice and thrice their breadth.

*Occurrence.*—The type specimen covers between a fourth and a third of one of the larger whorls of a *Nerinea goodellii* and parts of the two whorls preceding and following, and is met by another similarly radiating colony of which only a border portion is preserved, the line of contact of the two colonies being heaved up into a ridge. It is from the locality 1½ miles east of Malone station.

In the partially embedded cells and in the resulting apparent separation of the tubes from each other this species resembles *Berenicea microstoma* Mich., as illustrated in fig. 6b of Pl. I of Reuss's "Bryozoen, Anthozoen und Spongiarien des Braunen Jura von Balin bei Krakau,"[a] but it lacks the undulatory transverse furrows of that species and has the tubes less strongly inflated and proportioned much as in the *B. tenera* Reuss. The last-named species is, however, very different in having the tubular cells visibly in contact instead of separated by a conspicuous basal stratum that conceals their deeper and contiguous parts.

[a] Denkschr. k. Akad. Wiss., Math.-Nat. Classe, vol. 27. Wien, 1867.

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# MOLLUSCA.

## PELECYPODA.

### OSTREIDÆ.

#### Genus OSTREA Linnæus.

##### OSTREA sp.

Three imperfect valves of an ovate, thin-shelled ostreid, about 1½ inches in greatest dimension, lie partly embedded on a piece of blue limestone obtained from the Theta, 1½ miles east of Malone station, and may represent Ostrea as distinguished from Exogyra and Gryphæa. They are, however, incomplete in the region of the beaks and their precise relationship therefore remains somewhat uncertain. The inflation is moderate and due almost wholly to the strongly incurved border, the remainder of the valve being rather flat.

Since in general aspect they recall species of Ostrea in the stricter, and certainly at least represent it in the broader generic sense, while they do not seem referable to any of the hitherto described Ostreidæ of the Malone Jurassic, they are here provisionally listed as above.

##### GRYPHÆA MEXICANA Felix.

Pl. III, figs. 1–6.

*Gryphæa mexicana* Felix, 1891, Beitr. Geol. u. Pal. Mex., pt. 3, p. 178, pl. 27, figs. 30, 30a.

Shell rather small, more or less inequilateral and cuneate; adductor scar elongate, lightly impressed; margins of the valves not crenulated internally, the right valve very much smaller than the left, rounded-triangular, usually flat or exteriorly in part concave, thickened in the dorsal part; left valve triangular to crescentic-triangular, deeply excavated, strongly arched on the dorsal region, the posterior part more prominently so than the anterior, its beak high-arched, strongly incurved and rather bluntly (seldom freely) hooked, usually swinging a little backward, its posterior side strongly flattened or concave, the passage thence to the outer side more or less angulated or sometimes elevated as an obtuse fold, a similar but smaller flattening or concavity being often present on the shorter, anterior side, exterior side usually convex—sometimes flattish or concave—antero-posteriorly and either without bordering sulci or provided with an anterior or posterior sulcus or with both; the growth-lines sometimes acute and imbricated, especially on the anterior and posterior slopes, but on the exterior slope often more commonly thickened at irregular intervals into obtuse wave-like elevations and often here also swung upwards into a broad sinus. In specimens of smaller and

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medium sizes at least, the left valve is often ornamented with fine, radiating raised lines, including more conspicuous ones, which are rather remote, and numerous closely arranged, almost microscopically fine ones, there being usually 2 to 7 of the latter in each of the intervals between the former. This ornamentation is usually well expressed in very young examples, and these present considerable resemblance in form as well as sculpture to certain species of Plicatula, but in the arched valve, held beak upward and seen in exterior view, the longer side will appear on the right in the young Gryphæa and on the left in Plicatula, since the arched valve is the left in Gryphæa and the right in Plicatula and the posterior side of the shell is longer than the anterior in both genera. A very similar ornamentation is seen on the arched valve of Meek and Hayden's Black Hills Jurassic form, *Gryphæa calceola* var. *nebrascensis*. In exceptional specimens, *G. mexicana* approaches the latter species in form also, tending to a uniform antero-posterior convexity, even the posterior flattening being slight. Much more common than this, however, is the occurrence of specimens with anterior and posterior sides both strongly flattened or concave.

*Measurements.*—Specimens of an ordinary size give height, 43 mm.; length, 32 mm.; breadth, 17 mm.; but considerably larger specimens are often found.

*Occurrence.*—Common at several levels below the Iota conglomerates, a mile and a half east of Malone station, where scores were collected, and less so a few feet above similar conglomerates in an anticline in the east flank of Malone Mountain; in the latter locality associated with *Pleuromya inconstans*, *Modiola maloniana*, *Astarte malonensis*, *Exogyra subplicifera?* and *Serpula gordialis*. The species was also collected by Doctor Stanton, both at these and at the following localities: About a mile east of Finlay station; west side of Malone Mountain, west and also south of west from Malone station (at the last-named locality in Nos. 13 and 25 of his Malone Mountain section); from foothills west of Malone Mountain, about 2 miles north of its southern end; at the west base of the mountain, near its southern end; and from the east slope of the mountain, near its southern end, 200 or 300 (?) feet above the gypsum.

One of the most striking features of *G. mexicana* is the posterior flattening of the left valve, a feature of which is much more strongly expressed in this shell than in any other species of Gryphæa with which I am acquainted.

The prevailing size of the shell is not the same at all localities, some specimens of the largest average size coming from the west side of Malone Mountain; but at no locality in the Malone district does the shell average so small as the Oaxaca examples figured by Doctor Felix.

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## Genus EXOGYRA Say.

### EXOGYRA SUBPLICIFERA Felix.

Pl. IV, figs. 1–4.

*Exogyra subplicifera* Felix, 1891, Beitr. Geol. u. Pal. Mex., Pt. III, p. 177, pl. 27, figs. 6, 7.

From locality 1½ miles east of Malone station, and associated with most of the commoner fossils described in this paper, were collected 19 specimens, besides 8 obtained by Doctor Stanton. Two somewhat doubtful casts were also found, with *Gryphæa mexicana*, *Astarte malonensis*, etc., just above the beds of conglomerate, at the eastern base of Malone Mountain, in the anticline about 1 mile north of the southern end of the mountain.

The shells occur both free, or nearly so, and attached by nearly the whole of the left valve. The largest example from the Malone Hills has a length of 35 mm., but some of the smaller ones agree nearly in size with the Mexican specimens described and figured by Doctor Felix from the Cerro de Titania. The right valve has the beak strongly recurved laterally, and sometimes has the anterior dorsal border drawn across the umbonal cavity so as to form more or less of a cul de sac, and in the more nearly free examples is rather thin, deeply excavated, and ornamented with numerous imbrications which present distally an obtuse angle on the summit of convexity, and in some of the young examples may have 1 to 4 faintly expressed radial folds on the basal part. In young specimens the right valve is more or less triangular, broad across the distal part, and a little produced at the base; in the adult it usually becomes auriform.

The following is a translation of the original description by Doctor Felix, relating to the right valve, which is exceedingly characteristic and on which alone the species was established:

> It is of auriform—sometimes rather elongate, sometimes more broadened—contour, like the Cretaceous *Exogyra auricularis* Brongn. sp., which has been regarded by Coquand as a variety of his *E. plicifera*. On its inner surface it bears a variable number, mostly 5 to 8, of transverse folds, which are in strong relief, but do not extend across the entire shell breadth, by which sculpture it is especially distinguished from related forms. It may be taken for granted that if adult examples show this sculpture on their inner side, free or only umbonally adnate individuals will show it on their outer surface in at least as distinct a manner as the Cretaceous *E. plicifera* Coqu. possesses it.
>
> The length of the specimen in the middle amounts to 15 mm.

### EXOGYRA POTOSINA C. and A.

Pl. III, fig. 7; Pl. IV, fig. 7.

*Exogyra potosina* Castillo and Aguilera, 1895, Faun. Foss. Sierra d. Catorce, p. 3, Pl. II, fig. 9.

Doctor Stanton's collection contains six specimens that are referred to this species. All are larger than the Mexican type specimen fig-

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ured by Castillo and Aguilera. Three, of which one closely resembles the example of "*E. subnodosa* Münster," figured in Goldfuss's *Petrafacta germaniæ* (Pl. LXXXVI, fig. 8), are from the foothills west of Malone Mountain, about 2 miles north of the southern end of the mountain, there associated with *Gryphæa mexicana*, *Pinna quadrifrons*, *Pleuromya inconstans*, etc. The three others, representing a variety of more broadly triangular outline, are from the west base of the mountain, only a short distance north of its southern end. The latter station, according to Doctor Stanton's notes, may or may not represent the same horizon as the former and "is certainly several hundred feet above a horizon of *Gryphæa mexicana* and Nerinea."

The specimen, above compared to *E. subnodosa*, has a convexity of about 40 mm. and a lateral profile whose greatest extent, from beak to anterior part of base and extent transverse to the same, are respectively 86 and 55 mm. Corresponding dimensions in one of the larger and broader specimens from the second station above specified are respectively and approximately 39, 93, and 73 mm.

The following is a translation of Castillo and Aguilera's description of *Exogyra potosina:*

Shell elongated, oblique, laterally curved, of semilunar contour. Right[a] valve inflated, its major convexity situated near the umbo, incurved like the shells of Gryphæa; provided with an obtuse crest that traverses the shell in its entire length forming a curve concentric with the anterior margin; beak little free and gently recurved laterally. Left valve operculiform, depressed, and adapted to the concavity which the right valve forms; beak rudimentary. Surface provided with growth-laminæ more marked in the left valve, which is entirely lamellar; on the right valve are perceived two pliciform nodules, obtuse and imperfect, upon the indistinct crest of the shell. Length, 57 mm.

Castillo and Aguilera further describe the shell as intermediate between Exogyra and Gryphæa, noting that it approaches the latter genus both in the general form of the two valves and by preponderance of the vertical over the lateral curvature of the umbonal region. In the Texas specimens, however, at least sometimes, the lateral curvature seems to preponderate.

It is possible that the narrower and broader forms represent two species; but this does not seem probable, and they are here provisionally regarded as mere phases of one.

*Exogyra potosina* in the Sierra de Catorce, has been recorded only from relatively high beds, which Castillo and Aguilera have considered as Cretaceous. It apparently occurs only high in the Malone district also; but some of its associates in the latter district are apparently identical with the lower occurring *Pleuromya inconstans* (of the Theta and Alamitos); *Gryphæa mexicana* (of the Theta and Jurassic of Oaxaca); *Pecten insutus*, *Pinna quadrifrons*, *Lucina*

[a] Left, of authors generally, who regard the operculiform valve as the right in the inequivalve forms of this genus.

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*metrica*, and *Astarte malonensis* (*?*) (of the Theta)—forms which are themselves the common associates of *Trigonia calderoni* (Theta and Alamitos); *Astarte microphyes* (Theta and Jurassic of Oaxaca), etc.

## SPONDYLIDÆ.

### Genus PLICATULA Lamarck.

#### PLICATULA SPORTELLA sp. n.

Pl. III, figs. 8, 9.

Shell small, well inflated by the convexity of the broadly rounded, somewhat inequilateral and twisted, broadly attached right valve; left valve nearly flat, its margin rather thick; both valves strongly plicated to the correspondingly crenulated margins, the ribs about 10 on each valve; ribs of the left valve with broadly rounded summits, the furrows between them narrow, those of the right valve with narrower, more widely separated summits, and separated by round-bottomed furrows; surface of ribs and furrows on both valves crossed with imbricated growth lines.

*Measurements.*—Height, 8 mm.; length, 10 mm.; breadth, 5 mm.

*Occurrence.*—Malone Hills, 1½ miles east of Malone station. The type and only specimen is attached to a shell of *Nerinea goodellii*.

## LIMIDÆ.

### Genus LIMA Bruguière.

#### LIMA INTERLINEATA sp. n.

Pl. IV, figs. 5, 6.

Shell small, obliquely oval, the anterior border straight or very slightly convex, the oval being more elongate than that of *Lima crenulicosta* Roemer, and the lateral profile more nearly approaching that of *L. waconsis* Roemer; the convexity of the valves, however, agreeing more nearly with *crenulicosta*, and the beaks somewhat more elevated than in either of those species; either valve ornamented with about 22 radiating ribs; the ribs tectiform, having two faces that meet at an angle considerably greater than a right angle; the ribs separated by intervals about as wide as themselves, the middle of each interval marked by a raised line, or, in the case of a few of the posterior intervals, by two to three such lines. It belongs to the subgenus Radula.

*Measurements.*—Length and breadth of the oval, respectively, 16 and 12 mm.

*Occurrence.*—Represented by a right valve and several fragments from locality 1½ miles east of Malone station, and, of Doctor Stanton's collecting at same locality, by a left valve with moderately

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prominent anterior ear. Doctor Stanton also obtained a fragment from about a mile south-southeast of Finlay station.

LIMA (CTENOSTREON) RIOGRANDENSIS sp. n.

Pl. V, fig. 4.

Shell large and thick, equivalve, somewhat inequilateral, or obliquely round-oval (the base swung somewhat forward), ventricose, anteriorly gaping, radially large-ribbed; ribs broad and low-convex, about 11 or 12 in number on each valve, separated by flat-concave intervals about as broad as themselves; the surface marked with sinuous-concentric growth lines and coarse, laminated imbrications which present convexities upward and downward on the ribs and intervals respectively, the laminated imbrications in places thickened so as to nearly fill the shallow intervals. The ears of the type are broken off. The presence of a byssal sinus is indicated by the direction of the growth lines on the basal remnant of the anterior ear.

*Measurements.*—Height about 125 mm.; length about the same; breadth, 80.5 mm. The thickness of the shell varies from about 7 mm. on the basal slope to about 13 mm. in the dorsal region.

*Occurrence.*—Only the single type specimen is known. This was found on the upper part of the Theta outcrop, 1½ miles east of Malone station, associated with specimens of *Trigonia vyschetzkii*, *Astarte malonensis*, etc.

The species seems to considerably exceed in size *Ct. proboscidea* Sby., of the Oxford. The only Ctenostreon that has hitherto been known from North American rocks is an undescribed species reported by Hyatt from the lower Jurassic of Taylorsville, Cal.

## PECTINIDÆ.

### Genus PECTEN Klein.

PECTEN (CAMPTONECTES) INSUTUS sp. n.

Pl. IV, figs. 11, 12.

Shell pyramidal-subcircular, somewhat inequilateral, with greater anterior than posterior extent, inequivalve; left valve having a fair degree of convexity; right valve flattish-convex; beaks rather pointed, not rounded in well-preserved specimens, the right one but slightly inflated; anterior straight or slightly concave and posterior usually slightly convex (sometimes in part incipiently concave); dorsal margins of body of either valve making a right angle, or often considerably less than a right angle, with each other; anterior ear large, its hinge, or crest line, about twice as long as that of the posterior ear, and its anterior margin reaching about three-fourths as far

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in advance of the beaks as does the anterior margin of the valve itself, its byssal sinus angular or subangular; surface of both valves ornamented with numerous fine, closely set, rounded to flattened, radial, linear costellæ, separated by narrower, serially punctate, striæform grooves, and crossed by concentric growth lines, of which some at irregular intervals are more or less strongly imbricated; punctations commonly approaching the form of a circumflex accent, sometimes appearing dot-like, very closely ranked.

*Measurements.*—Height, 39 mm.; length, 34 mm.; breadth, 10 mm. (right valve 3, left 7).

*Occurrence.*—About 50 specimens were collected, in the Malone Hills, 1½ miles east of Malone station, the species ranging nearly throughout the fossiliferous Theta there exposed; in foothills about 1 and 2 miles a little south of east from Finlay station; at a point about 2 miles west of Malone station; about three-quarters of a mile farther south (all of the four last-named localities representing the same or nearly the same horizon, No. 13 of Doctor Stanton's Malone Mountain section); and at the anticline in the east slope of Malone Mountain, nearly a mile north of its southern end.

Before obtaining a copy of Felix and Lenk's Beiträge zur Geologie und Palaeontologie der Republik Mexico I had characterized and named in manuscript the above-described common Malone fossil, giving it the specific name *insutus*, in allusion to the peculiar stitched appearance of the seams between the ribs. Its ornamentation closely resembles that of the *Lima comatulicosta*, described in that work, from the upper Jurassic of Mexico. It differs, however, in several respects from that form, as described and figured by Doctor Felix.[a] It is provided with ample ears, of which the anterior is several times the larger; it is inequivalve; its beaks, instead of being rounded, as described and figured by Doctor Felix in his *Lima comatulicosta*, are, when perfectly preserved, rather pointed; and, finally, its outline is less obliquely or anteriorly elongated, sometimes even approaching in the body of the valves an equilateral or circular outline with a pyramidal summit, though usually rather oblique and somewhat elevated.

The break possibly indicated at the position for an ear in fig. 5 (loc. cit.) of *Lima comatulicosta*, the apparent identity of the costal and intercostal ornamentation of the Malone Pecten with that shown in figs. 1, 1a, 3, 3a of the Cerro de Titania shell, and the fact that, unless the *Pecten insutus* be it, the *Lima comatulicosta* is not known from the Malone district, while its appearance there might reasonably be expected (since at least two[b] of the seven lamellibranchs described by Doctor Felix from the Upper Jurassic of the Cerro de Titania

[a] Beitrilge, etc., in Palaeontographica, vol. 37, p. 178, Pl. XXVII, figs. 1, 1a, 3, 3a, 5.

[b] *Exogyra subplicifera* and *Gryphæa mexicana*.

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have been found to be common to both localities), are circumstances which at one time led me to regard the alleged Lima as probably identical with the common Pecten of Malone. But that the differences of form are considerable, as above shown; that Doctor Felix gives two figures of *Lima comatulicosta* which agree essentially with each other in all respects in which either differs from *Pecten insutus;* that he compares his fossil with a European species of Lima [a] from the coral rag, and that the peculiar intercostal punctation is known to occur both in Lima and in Pecten, are considerations in view of which the assumption that the Mexican fossil has been wrongly referred to Lima is not warranted.

The radially ornamented outer layer of this shell rapidly weathers off, leaving a shiny black surface, so that sometimes the shell appears smooth or bears only subdued concentric markings.

The specimen figured represents the more circular phase of the species and shows the beaks less pointed than they appear in most examples.

## AVICULIDÆ.

### Genus GERVILLIA Defrance.

#### GERVILLIA CORRUGATA sp. n.

Pl. IV, figs. 8–10.

Shell inequivalve, very inequilateral, obliquely elongated and curved; hinge provided with several cartilage-pits, the one anterior to the beaks being relatively small; the left valve crescentic as viewed from above, sigmoid as viewed from without, its beak curved forward, inward, and downward, its postero-basal part curved backward, upward, and inward; the right valve (including beak) flattened, its posterior umbonal slope monoclinally angulated, the steep and narrow post-umbonal slope, separating the anterior, anteroposteriorly flat-convex, proximo-distally flat or slightly concave main part of the valve from the relatively depressed posterior wing; anterior wing small or of moderate size, that of the left valve a little contorted, posterior wing rather large, its angle drawn out posteriorly to a point, owing to the strong emargination of its posterior border; umbo of left valve radially corrugated, the adjoining part of the left posterior wing similarly ornamented on a smaller scale, remainder of left and the right valve marked with ordinary growth-lines.

*Measurements.*—Height,[b] 25 mm.; length, 38 mm.; breath, 12 mm. Portions of several large specimens indicate at least twice these dimensions.

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[a] *L. comatula* Buvignier.

[b] Height and length taken as usual, perpendicular and parallel to the hinge-line.

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*Occurrence.*—As yet known only from the Malone Hills, 1½ miles east of Malone station, and only moderately common in the lower part of the Theta beds of that locality, occuring with several of the smaller species of Gastropoda. *Gryphæa mexicana*, which ranges much higher, is also one of its commoner associated fossils. Twenty-three imperfect specimens and fragments were collected.

### GERVILLIA CINDERELLA sp. n.

Pl. V, fig. 1.

Shell subequivalve, moderately inflated, somewhat flattened on the flank, falciform, the basal region being much produced posteriorly, its terminal part tapering; basal margin long, straight, convex; posterior border concave; flank-region limited supero-posteriorly and in part anteriorly by an abruptly rounded shoulder, the surface being drawn steeply in to the base of the wing; posterior shoulder continuous from the beak to the upper part of the posteriorly produced basal region, its axis gently curved with concavity looking upward and backward; anterior wing inflated above, concave and more distinct from the body of the valve below; posterior wing large, falcate (?) (largely broken off in the type), surface bearing delicate concentric growth lines.

*Measurements.*—Height, 32 (plus several) mm.; length, about (probably a little more than) 57 mm.; breadth, 19 mm.

*Occurrence.*—One specimen, wanting the cardinal region, was found by Doctor Stanton in the horizon of the broader phase of *Exogyra potosina* at the west base of Malone Mountain, a short distance north of the southern end.

### GERVILLIA ? RIOGRANDENSIS sp. n.

Pl. V, figs. 2, 3.

Another species of lamellibranch, here provisionally referred to Gervillia, was found at the west base of Malone Mountain, associated with *G. cinderella*. It is represented by a cast, of which considerable of the upper posterior region has been removed by weathering, and which bears fragments of the shell of the left valve. The form is less elongate and more compressed than that of *G. cinderella;* the anterior border is concave, the ventral border slightly so, the adjoining lower part of the flanks being slightly hollow, owing to the strong compression of the ventral region. As compared with *G. cinderella*, the antero-ventral border is more prominent and regularly rounded. The shoulder separating the flank from the posterior wing appears, from the cast of part of it, to have been much more gently molded, and this wing seems to have had much greater development in its lower part; surface, as impressed on the mold of a shell fragment, marked with

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fine growth lines, of which some, occurring at short subregular intervals on the distal parts, are more strongly imbricated than others.

*Measurements.*—Height, about 40 mm.; length, 38 mm. (plus 5?); breadth, 17 mm.

*Occurrence.*—Known only by the above-described specimen, associated with *Gervillia cinderella*, *Exogyra potosina*, *Pleuromya inconstans*, etc.

## MYTILIDÆ.

### Genus MYTILUS (Linn.) Brug.

MYTILUS NUNTIUS sp. n.

Pl. VI, figs. 4, 5.

Shell small, equivalve (or slightly tortuous-inequivalve?), rather compressed, the right or left profile arched cuneate-oblong, considerably less attenuated anteriorly than that of the somewhat similarly proportioned recent species, *Mytilus afer* Gmelin, the angle made by the anterior margins of the cast being about three-fourths of a right angle; beaks terminal, subacute, gradually and moderately deflected upward, directed much more forward than upward; valves apparently smooth or marked only with concentric growth lines.

*Measurements.*—Length (oblique) of lateral profile, 21 mm.; breadth of same, 10 mm.; breadth of shell, about 6 mm.

*Occurrence.*—A single well-preserved cast, bearing thin remnants of the shell, was found among the lower occurring fossils (*Gervillia corrugata*, *Pleurotomaria circumtrunca*, etc.) of the Theta 1½ miles east of Malone station. A form without trace of shell, observed on the matrix of a *Trigonia vyschetzkii* from the same locality, probably represents a valve of the same Mytilus and indicates for it a somewhat larger size.

Though the longitudinal axis of this shell is arcuate, the arching is so gentle that the outline approaches that of the straighter-profiled *Mytilus afer*, as figured by Tryon,[a] more than one of such strongly curved forms as *sublævis*, *eduliformis*, and *decussatus*.

### Genus MODIOLA Lamarck.

MODIOLA MALONIANA sp. n.

Pl. VI, figs. 1, 2.

Shell of moderate size in its genus, oblong-trapezoid, gently arched, broadest near the middle, the anterior and posterior regions rather narrow and elevated, the height being greatest at or in advance of the posterior fourth; beaks small and only moderately elevated above the hinge line, placed close together, nearly or quite in contact anteriorly, their dorsal summits forming rather narrow longitudinal ridges from

[a] Struct. and Syst. Conchol.

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either of which there proceeds to the posterior part of the basal margin a low, broadly rounded, umbonal swell, below which in the intermediate region the flanks are concave; surface nearly plain, marked only with ordinary growth lines, some of which are imbricated.

*Measurements.*—Height across umbonal region, 11 mm.; same at highest section of the shell, 12.5 mm.; length, 37.5 mm.; breadth, 11 mm. Another example attains a length of 43 mm.

*Occurrence.*—The type is from locality 1½ miles east of Malone station, which has yielded two other specimens. I have found a single example also, associated with *Pleuromya inconstans*, *Astarte maloneusis*, *Exogyra subplicifera?*, *Gryphæa mexicana*, and *Serpula gordialis*, at the eastern base of Malone Mountain, in the transverse anticline 1 mile from its southern end, just above conglomerates. Two additional specimens were obtained by Doctor Stanton, one from the anticline just mentioned and one from about 1 mile east of Finlay station.

### MODIOLA GENICULATA sp. n.

Pl. VI, fig. 3.

Shell small among its congeners, much shorter and higher relative to its breadth than *M. maloniana*, geniculate-trapezoid, the vertically expanded posterior half of the shell being rather suddenly deflected downward and backward so that its axis makes an angle of about 45° with the horizontal cardinal border of the vertically smaller anterior half; breadth less than the height, greatest about the middle; beaks moderately raised, little inflated; flanks concave in the mid region below the umbonal convexity; surface apparently marked only with the ordinary growth lines.

*Measurements.*—Height, 16 mm.; height of section across middle, 12.5 mm.; length, 25.5 mm.; breadth, estimated from convexity of one valve, 10 mm.

*Occurrence.*—A single left valve was collected by Doctor Stanton about 1 mile east of Finlay station.

## PINNIDÆ.

### Genus PINNA Linnæus.

### PINNA QUADRIFRONS sp. n.

Pl. VII, figs. 1–8.

Shell of medium size in its genus, elongate-cuneate; anterior region inflated, in cross section bicuspidately round-oval to quadrate-oval; posterior region rather compressed, in cross section nearly rhombic; valves meeting by their ventral margins at an acute and more or less compressed or cariniform angle and by their dorsal margins at a somewhat similar angle; from their anterior, more convex part, be-



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coming at first feebly and then, on the middle and posterior region, strongly and abruptly obtuse-angulated along a radial line a little above the middle, so that either valve presents two slopes—a dorsal, which is flat or in part feebly concave, and a somewhat wider ventral, which retains some convexity even on the posterior part; dorsal slope of either valve ornamented with 10 to 15 compressed and gently elevated radial costellæ, which are separated by intervals wider than themselves and obliquely scored by numerous growth lines that give the costellæ a more or less granulated or crenulated appearance; ventral slope marked only with strong, pliciform, for the most part very oblique growth lines. The summit of the supra-median angle is the locus of a linear hingelike plait, or gore, by whose ready erosion the valves are often cleft, especially along the middle and posterior region, each into two valvelike segments, so that broken specimens which include only that region appear not only tetragonal and quadrilateral, but also quadrivalvate.

*Measurements.*—Height (across larger end), 56 mm.; breadth (across same), 30 mm.; length, 240 mm.; all approximate.

*Occurrence.*—One and a half miles east of Malone station. This is one of the most abundant fossils of the Theta subdivision in that locality and ranges nearly throughout the known fossiliferous thickness of it. It usually occurs in sections varying in size from less than 1 inch to 4 or 5 inches long, of which about 80 were here obobtained. Some have been subjected to pressure in such a manner as to make them nearly square in cross section. Doctor Stanton also obtained several on the west side of Malone Mountain, as follows: One in No. 25 of his Malone Mountain section, 2 miles south of west Malone station; 2 from a foothill about 2 miles northwest of the southern end of the mountain, and 6 from the west base of the mountain, a short distance north of its southern end. Part of those (casts) from the last-named locality are more than usually compressed, rapidly expanded, and somewhat curved, and at first sight suggest a distinct species or variety; but others are of intermediate form and some bear shell remnants with seemingly characteristic *quadrifrons* ornamentation, so that, while individual variation may have played a part, the exceptional form should probably be attributed chiefly, if not wholly, to the distortive influence of the orogenic forces that have acted upon the matrix containing them.

## ARCIDÆ.

### Genus ARCA Linnæus.

#### ARCA TAFFII sp. n.

Pl. VI, figs. 7, 8.

Shell small, ventricose, broader than high, of moderate length; beaks strongly arched, inrolled, and brought into contact; posterior

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slope angulated and strongly flattened (radially costate?); anterior slope a little excavated on the upper part, separated from the outer slope by a rounded shoulder, ornamented with a few strongly elevated radial costæ separated by comparatively wide intervals, in each of which is a feebler linear costella; outer slope flattened, radially costate, becoming closely cancellated on the middle and strongly so on the ventral part; ventral margin straight, not crenulated. There are 20 of the costæ on the outer slope, small, with their rounded summits subgranulated by the cancellation, and separated by intervals of about their own width. On the summit of the umbo the axis of flattening is inclined forward.

*Measurements.*—Height, 10.5 mm.; length, 19 mm.; breadth, 12 mm.

*Occurrence.*—One and a half miles east of Malone station; represented by only one example.

The ornamentation of the posterior slope is concealed in the type specimen. A radiately costate ornamentation upon it is inferred from the fact that the species seems to agree subgenerically with Gray's Calloarca as described and figured in Tryon's Structural and Systematic Conchology. A slight inequality of the valves in the umbonal region is doubtless a distortion due to stratigraphical disturbance. The specimen does not disclose the characters of either the hinge or the ligamental area.

### ARCA? DUMBLI sp. n.

Pl. VI, fig. 6.

Shell small, only moderately inflated, rather elongate-trapezoidal, the anterior side short and subvertically truncate, the posterior long and obliquely truncate; the base gently convex; the moderately elevated beaks situated at the rear limit of the anterior third; anterior slope small, concave, wing-like, with supero-anterior corner nearly a right angle, separated from the outer slope by a posterior umbonal angulation, which becomes obsolete distally; posterior slope concave, separated from the outer by a strong, proximally subacute, distally obtuse shoulder-like angulation, the two apposed concave slopes forming together a sort of wing with obtuse corner; the anterior slope ornamented with a few narrow, distally obtuse radial folds, the outer slope with ordinary and strong concentric growth-lines, radial lines, if originally present here, having been feeble and obliterated by weathering in the types, the posterior slope and the summit of its limiting angle having numerous radiating raised lines and striæ.

*Measurements.*—Height, 16.5 mm.; length, 30 mm.; breadth, about 12 mm.

*Occurrence.*—One and a half miles east of Malone station; represented by 5 specimens.

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The hinge characters of this shell are unknown. While the general form permits little doubt that it is one of the Arcidæ, there is less certainty of its generic position, and it is placed only provisionally under Arca.

The species is named for Mr. E. T. Dumble, late State geologist of Texas.

## Genus CUCULLÆA Lamarck.

### CUCULLÆA? TEXTICOSTATA sp. n.

Pl. VI, figs. 9, 10.

Shell ventricose, short, subtriangular, somewhat pointed inferoposteriorly, rounded anteriorly, the posterior slope flattened and making an angle with the outer slope; beaks well inflated and elevated; entire surface marked in a crowded manner with radiating linear costellæ and in large part with erect concentric lines of imbrication, of which the latter are the finer and more crowded (seen to advantage only when magnified), and the former the more conspicuous and more persistent under weathering. A considerable part of the surface when magnified appears woven, like cloth or miniature basket work, except for the alternating arrangement seen in the latter. This woven ornamentation resembles that seen in *Arca taffii*, the radial costellæ being, however, much finer and more numerous than in that anteriorly and posteriorly otherwise ornate and altogether differently shaped arcid.

*Measurements.*—Height, about 29 or 30 mm. (?); length, 34 mm.; breadth, 24 mm.

*Occurrence.*—One specimen and a fragment of a second; 1½ miles east of Malone station.

In the absence of any knowledge of the hinge of this shell it is not possible to be sure whether it is a Cucullæa or an Arca. The ornamentation—primarily radial and secondarily cancellated—is of a type more common in the latter genus; but the species is put provisionally in Cucullæa, under the subgenus Trigonarca, on account of its triangular form.

### CUCULLÆA TRANSPECOSENSIS Cragin.

*Cucullæa transpecosensis* Cragin, 1893; Fourth Ann. Rept. Geol. Survey Texas, pt. 2, p. 175.

The genus Cucullæa is not represented by abundance of individuals in any of its species in the rocks of the Malone formation in Texas, and so rare is the massive and ventricose *C. transpecosensis* that, despite careful collecting for many days at the locality which yielded Messrs. von Streeruwitz and Wyschetzki the type, the latter still remains the only specimen known of this species.

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As it has not been practicable to restudy the type, the original account of the species is here reproduced, which is as follows:

Shell large and thick, ventricose (subrhomboidal?); beaks large, remote from the anterior extremity, their summits very obtuse as viewed from the side or from above, their apices less compressed and less free than in *C. terminalis* or *C. gratioti*;[a] anterior dorsal border prominent and compressed, subaliform, the surface included between it and the [anterior[b]] line of the beaks being ornamented with raised radial lines, posterior dorsal angle (apparently) shorter and lower than the anterior, posterior umbonal slope prominently angulated, the angulation succeeded on the inner side by a pronounced sulcus, which is in turn limited on its inner side by another angulation less prominent than the first: hinge-area broad, divaricate-grooved; anterior lateral denticles four (and one rudimentary), long, strong, and horizontal, their abruptly deflected inner termination being relatively very short. Mesial and posterior denticles unknown.

*Occurrence.*—Collected by Mr. von Streeruwitz about 1 mile northeast[c] of Malone, El Paso County, with *Venus maloncnsis*[d] and other forms, as mentioned under that species. Comanche series.[e]

In size this shell apparently exceeds the other known species of Cucullæa from the Comanche series of Texas.

## CUCULLÆA CATORCENSIS C. and A.

*Cucullæa (Trigonarca) catorcensis* Castillo and Aguilera, 1895, Bol. Com. Geol. Mex., No. 1, p. 5, Pl. IV, figs. 1, 4, and 5.

Two small Cucullæa casts, of medium ventricosity, obtained below the Iota conglomerates, 1½ miles east of Malone station, and two from above similar conglomerates in the eastern base of Malone Mountain, in the anticline about 1 mile north of its southern end, are referred to the young of this species.

The following is a translation of Castillo and Aguilera's description of *Cucullæa catorcensis*, as given (loc. cit.) in their "Fauna Fosil de la Sierra de Catorce:"

Shell bulky, very convex, of quite variable contour, oval in the young examples, subquadrangular in those which are more developed, and subtrapezoidal in the adults. Beaks broad, very prominent and little removed from one another, situated in the anterior third and nearly terminal in the adult examples, provided with a carina on the anal side. Buccal region very much more short than the anal, rounded on the extremity, a little excavated near the cardinal border

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[a] *C. terminalis* Con. and *C. gratioti* Hill, of the Comanche Cretaceous.

[b] Reads "posterior," by error, in the original.

[c] The same locality is herein generally called "1½ miles east of Malone station," and is perhaps a little short of the latter distance, so far as occurrence of the larger number of the fossils is concerned. I have understood that all of the fossils obtained from this spot in 1890 were actually collected by Mr. Wyschetzki; and if so, the name of Mr. von Streeruwitz was probably put on the label in view of his having been in charge of the trans-Pecos division of the Texas survey.

[d] *Astarte maloncnsis* of the present writing.

[e] For explanation of the manner in which the few fossils known from this locality in 1893 were at that time placed in the Comanche series, see Introduction. Instead of "Comanche series," read Malone formation.

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with which it forms an acute angle. Anal region obliquely truncate on its extremity, excavated or concave in the vicinity of the beaks, limited by a well-marked carina which traverses the shell from the beak down to the posterior extremity at its junction with the inferior border of the shell; the carina is quite acute near the beak and becomes more obtuse in proportion as it recedes from it; the umbonal region, thus circumscribed by the umbonal crest, forms a sort of corselet, quite marked and excavated. Middle region of the shell convex and in the form of a triangle limited by the anal crest and the other less developed which separates it from the buccal region; the major convexity of the shell is just adjoining the anal crest and near the beaks. Ligamental area not very much excavated and of regular dimensions. Cardinal border straight, in some specimens nearly as long as the shell, but in others much shorter; anterior border obliquely rounded; inferior border nearly straight and parallel to the cardinal border, joining by means of a curve with the posterior border, which is oblique, slightly curved, and in the young forms nearly parallel to the anterior border. Surface of the shell provided with concentric lines of growth which have suffered interruptions and constitute more or less prominent corrugations.

Length, 60.62 mm.; breadth with relation to the length, 0.58.

Locality: Arroyo de Alamitos, on the Alamitos rancho, in the Sierra de Catorce.

By breadth ("ancho") in the above is meant the dorso-ventral dimension called height by some writers. The lateral breadth, called thickness ("espesor") in the "Fauna Fosil," is not stated.

The massiveness of this shell, its ventricose form, its broad beaks, and the demarcation of the middle from the posterior umbonal slope by a cariniform angulation, are features which might seem to indecate that *Cucullæa catorcensis* should be referred to the Texan *C. transpecosensis;* but the very prominent and subterminal beaks, and (so far as the description indicates) the absence of a second, or inner, angulation on the posterior corselet and of raised radial lines on the anterior umbonal slope in *C. catorcensis*, appears to sufficiently distinguish the latter as a valid species.

### CUCULLÆA CASTILLOI sp. n.

Pl. VI, figs. 11, 12.

Shell of moderate size in the genus, short-trapezoidal; ventricosity of medium degree, greatest considerably above the middle; anterior side short, rounded; posterior side straight, obliquely truncate; base gently convex; the infero-posterior part of the shell somewhat pointed, owing to a prominent, rapidly rounded shoulder that runs from either beak to the junction of the ventral with the posterior border, separating the outer convex slope from the posterior slope, which latter is strongly and concavely depressed, being strongly inflected near the shoulder and turning outward again about midway of its extension toward the posterior border, to form a prominent

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and sharp keel by union with the corresponding border region of the opposite valve; anterior umbonal slope only feebly angulated or shouldered; beaks narrow, high-arched, approximated, placed slightly in advance of the middle third; flank region marked with concentric growth lines; posterior slope finely and closely striate.

*Measurements.*—Height, 39 mm.; length, about 48 mm.; breadth, about 34 mm.

*Occurrence.*—Two examples were collected by Doctor Stanton in foothills at the northwest end of Malone Mountain, about 2 miles east-southeast of Finlay station. Neither shows the ornamentation of the anterior slope.

The species is named for the late Prof. Antonio del Castillo, founder-director of the Geological Institute of Mexico.

## NUCULIDÆ.

### Genus LEDA Schumacher.

#### LEDA? NAVICULA sp. n.

Pl. VI, fig. 13.

Shell fairly well inflated, elongate-ovate, anteriorly not shortened, posteriorly produced and gradually narrowed or subrostrate; the anterior subhorizontal and posterior gently declined parts of the dorsal side each forming a small concavity adjoining the beak, anterior side rounded, base long and straight-convex for the greater part, its posterior part ascending obliquely; beak small and little salient, placed a little back of the anterior third.

*Measurements.*—Height, 11.5 mm.; length, 25 mm.; breadth, about 10 mm.

*Occurrence.*—A cast of a left valve was found embedded in the rock fragment bearing one of the specimens of *Unicardium semirotundum* collected by Doctor Stanton at the anticline on the east slope of Malone Mountain about 1 mile north of its southern end.

A cast of a small, posteriorly produced lamellibranch, which was supposed in the field to be one of the Nuculidæ and which may have been a Leda, was observed in Theta a mile and a half east of Malone station. It was accidentally destroyed in attempting to remove it from the matrix. A rough sketch of it, preserved in my notes, indicates a shell similar in form to that above described, but smaller. It may be referred to *Leda? navicula*, but is represented as having the margins crenulated, while this character, if it belonged to the latter species, can not be distinguished in the type as preserved.

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## TRIGONIIDÆ.

### Genus TRIGONIA Brug.

#### TRIGONIA VYSCHETZKII Cragin.

Pl. VIII, figs 1, 2; Pl. IX, figs. 1–3.

*Trigonia vyschetzkii* Cragin, 1893, Fourth Ann. Rept. Geol. Survey Tex., pt. 2, p. 215; and, 1897, Jour. Geol., vol. 5, No. 8, pp. 816, 817.

Cf. *Trigonia sologureni* Felix, 1891, Beitr. Geol. u. Pal. Mex., pt. 3, p. 179, Pl. XXVII, figs. 2, 2a.

Shell large, of moderate convexity, transversely subquadrate; postero-dorsal side straight; anterior and posterior sides truncate; base gently curved; beaks only moderately arched; area flattened, occupying about one-fourth of the valve, bordered above and below by a tuberculated ridge or angulation, and traversed by a median groove which is accompanied by a third such ridge less developed than those of the border, a large distal part of it obliquely crossed in most instances by numerous strong, more or less irregular and interrupted folds, or ornamented on the proximal part with rows of tubercles by whose increasing confluence on the intermediate and distal parts the folds are produced, the tubercular endings of these folds usually descending across the entire outer slope of the bounding ridge, and in some cases even passing a little beyond it; escutcheon depressed, crossed with a series of transverse, somewhat oblique, straight, or in part slightly curved, tubercular costellæ; preäreal surface ornamented with about 15 gently curved nodose costæ, which are subvertical near the infraäreal ridge and make with the latter at first an acute and then approximately a right angle, descending for the most part obliquely, though steeply, to the base; the costæ attenuated and simpler near the area, becoming resolved into irregularly more and more robust nodes as they recede from it, the posterior and intermediate costæ thus enlarging throughout, while a few of the shorter anterior ones, turning forward at their lower ends across the flattened front of the shell, are here again reduced to nearly simple ridges which dwindle and disappear before reaching the valve margin; nodes mostly close ranked, commonly 12 to 16 on the larger ribs of adult shells, rounded, often more or less compressed so as to trend with the growth lines, a rib often having a single very large node near the basal margin of the valve especially thus elongated; intervals between the costæ coarsely concentrically striate. The separation of the siphonal currents is indicated, as in the Clavellatæ and Scabræ, by a ridge on the interior of the shell. The ornamentation shows considerable mutability, and a variety occurs in which the entire area is covered with small compressed tubercles. In one specimen the costellæ of the escutcheon are simple.

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*Measurements.*—Approximately, height, 76 mm.; length, 87 mm.; breadth, 50 mm. Two very young examples have these dimensions, respectively, 16, 17, 10, and 25, 27, 15 mm.

*Occurrence.*—So far as the collections show, this Trigonia does not occur in the Malone district, except in the Malone Hills and in the Theta subdivision of the Trio section. In these, however, 1½ miles east of Malone station, it becomes numerically one of the commonest fossils of the Malone formation. In the rich collecting tract there, on the basal slopes of the Truncate mound and the southeast base of hill *C* of the Trio, and especially on the western basal slope of the former, it was found by scores, in one or two places being agglomerated in beds, mingled more or less with other fossils. Between 75 and 100 specimens of it are represented from this tract. But if the shells of other Malone fossils, as here preserved, prove fragile under the rigorous temperature changes of a plateau climate, that of *Trigonia vyschetzkii* is so especially, and of the large number collected many are in half-released fragments, and comparatively few make even tolerably fair cabinet specimens. I also found this fossil about half a mile west-northwest of this locality on the south side of the flat saddle that separates the Trio from the low gypsum-parted ridge which continues the hill range in that direction.

The series of quadrate pits mentioned by Lycett[a] and cited by Steinmann[b] as occurring posteriorly on the interior of the valve near the ventral margin in Quadratæ, is lacking in *T. vyschetzkii*. The form differs from that of the Quadratæ and agrees with that of the Clavellatæ in being considerably longer than high, yet agrees with Quadratæ and differs from Clavellatæ in being quadrilateral instead of subtriangular. In having the escutcheon ornamented and in some—usually slight—tendency which the areal folds manifest to infringe on the general surface below the limiting angle, on the posterior region, the shell agrees with the Quadratæ.

The *T. vyschetzkii* is thus seen to be closely related to the South American *T. transitoria* Steinm., upon which and the related *T. herzogi* Hausmann, of South Africa, Steinmann, in 1882, proposed to add *Pseudo-Quadratæ*[c] to the previously known sections of Trigonia. Its profile is usually less elongate and the ornamentation, especially that of the area and escutcheon, less coarse than in *T. transitoria*, the folds of the area descending the lower slope of the limiting angle, but descending only a little (sometimes not at all) below it on the posterior region.

Normal casts of *Trigonia vyschetzkii* are differently proportioned from that which—from Tlaxiaco, Mexico—Doctor Felix figures as

[a] Mon. Brit. Foss. Trigon., p. 100.
[b] Neues Jahrb. für Mineral., 1882, vol. 1, p. 221.
[c] Loc. cit., pp. 219–228, Pls. VII–IX.

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the type of his *T. sologureni*,[a] a shorter, more elevated, and much more ventricose form being indicated for the latter species. But the cast of *T. ryschetzkii*, in one or two of our specimens, somewhat approaches that of *T. sologureni* in form, while several species of fossils are common to Malone and Tlaxiaco; so that it is desirable to compare actual shells of these two species with one another as well as with the shell of *T. transitoria*.

### TRIGONIA GOODELLII Cragin.

Pl. X, figs. 1, 2.

*Trigonia goodellii* Cragin, 1897, Jour. Geol., vol. 5, p. 816.

Shell of about medium size in its genus, produced ovate, ventricose; valves thick; beaks situated near the rear limit of the anterior fourth, low, strongly inflated, in contact, their posterior slope strongly angulated to form the limiting angle of the area; area flattened, nearly plain, having numerous fine oblique growth lines, with a few small folds crossing it near and concentric to the beaks, these folds being continuous of and making an angle with those in front of the area, some low tubercles along the marginal angles, and a faint mesial sulcus; escutcheon bearing only inconspicuous folds which radiate from the ligament, those of the proximal part being nearly transverse to the length of the escutcheon and continuous with those of the corresponding part of the area; general ornamentation consisting of a series of ribs, which on the posterior part of the preäreal surface are large, obtuse, and plain or subtuberculated, separated by round-bottomed valleys of about their own width, and descend almost vertically (the earlier ones more obliquely forward) from the inferior border of the area, increasing in size each to an elbow-like angle, at which they turn abruptly forward, becoming reduced in size to costellæ in front of these elbows and partially resolved each into a series of small tubercles, these costellæ being accompanied each by one or two similar ones in the intervals between them, the costellæ diminishing gradually in size and swinging into the course of ordinary growth lines on the anterior region, and there becoming continuous and like strong reversed imbrications, each presenting its acute and more elevated border dorsad. The series of costal elbows radiates at first downward and then obliquely downward and backward from the beaks.

*Measurements.*—Height, 42 mm.; length, about 58 to 60 (plus?) mm.; breadth, 35 mm.

[a] Versteinerungen aus dem oberen Jura des Cerro de Titania bei Tlaxiaco im Staat Oaxaca, 1891, Beitr. Geol. u. Pal. Mex., pt. 3, Palaeontographica, vol. 37, p. 179, Pl. XXVII, figs. 2, 2a.

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*Occurrence.*—One and a half miles east of Malone station. Besides the original example which the Messrs. Goodell discovered, and from which the illustration and measurements have been taken, 17 other imperfect specimens and fragments were obtained at this locality, some of them indicating dimensions perhaps a fourth larger than those of the type.

It will be seen from the description that the ornamentation of *T. goodellii* is variable. This, however, is true of most Trigonias, and not least so of those of the section, Undulatæ, to which this species belongs.

None of the Old World Undulatæ known to me corresponds very closely with *T. goodellii*. Several of those from the Great Oölite, which is so rich in Undulatæ, bear more or less resemblance to it; but the strict analogue, if found, may be expected to occur in the Tithonian.

The species was named after the late Mr. Robert Wood Goodell, whose kind services in assisting me to determine the age of the Malone formation I have particularly acknowledged in my article on the "Discovery of marine Jurassic rocks in southwestern Texas," the paper in which the species was first briefly characterized and named.

A Trigonia cast, showing nothing of the ornamentation, but indicating the general form of *T. goodellii*, having still larger dimensions than any of the above, and belonging not improbably to this species, was obtained by Doctor Stanton from conglomerate on the west face and near the top of Malone Mountain. It gives the following measurements: Height, 62 mm.; length, 72 mm.; breadth, 46 mm.

### TRIGONIA CALDERONI (C. and A.).

Pl. IX, figs. 4–6.

*Goniomya calderoni* Castillo and Aguilera, 1895, Bol. Com. Geol. Mex., No. 1, p. 9, Pl. V, figs. 17, 18.

Shell elongate-trapezoid, very inequilateral, moderately inflated, the region of greatest convexity extending from the umbones downward and backward; anterior region relatively short and of considerable height relative to the posterior, the anterior contour rounded; posterior region strongly produced backward and inclined a little upward, gradually and strongly tapered toward its extremity, which is obliquely truncate and looks backward and upward, its flanks more or less flattened; base gently convex below the beaks, ascending thence anteriorly in an easy convex curve and posteriorly slowly in a long and nearly straight line; beaks but moderately elevated, their apices curved inward and somewhat backward and downward; escutcheon rather large and long, plain; area of moderate width, flattened, traversed lengthwise by a mesial groove, and transversely linear-plicate,

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the plicules separated by striæ; preäreal surface ornamented with two sets of ribs, of which the anterior ribs are acute, upwardly-imbricate, remote, subhorizontal, with gentle sigmoid flexure, presenting a slight upward convexity below the beaks and a downward one farther forward, and alternately reach the more anterior ribs of the other set; posterior ribs thicker, more obtuse, and more narrowly intervaled than the anterior, nearly straight, and directed steeply downward and backward from the limiting angle of the area, the proximal of these being the more nearly vertical and the distal and independent ones more oblique, the intermediate ones being the longest. Slight irregularities sometimes appear in the course of the anterior ribs, each of which, in one example, bears a small dorsally directed angle at the summit of its infraumbonal convexity.

*Measurements.*—One of the Texan examples, which has a length of 58 mm., indicates for the shell in part restored, a height of 32 mm. and a breadth of 23 mm., approximately.

*Occurrence.*—The Malone formation yields this fossil rather sparingly. Eleven specimens and characteristic fragments are represented. Eight of these are from the Malone Hills, 1½ miles east of Malone station; the others were collected about a mile east of Finlay station.

In the character of the preäreal ornamentation, the species presents considerable resemblance to *Trigonia sulcataria* Lamarck, as figured by Lycett on Pls. XXVI and XXVIII of his British Fossil Trigoniæ, a species which has been referred to the Undulatæ, but is shown by Lycett to belong to the Scabræ. The plain escutcheon, however, at once separates *T. calderoni* from the Scabræ, and the same and all of the other external characters refer it to the Undulatæ.

### TRIGONIA PROSCABRA sp. n.

Pl. X, figs. 3–6.

Shell small, crescentic-ovate or subsemicircular, the upper border strongly excavated, anteriorly inflated, gradually becoming more compressed toward the posterior extremity; beaks somewhat produced and recurved; escutcheon large, broader than the area, ornamented with rather remote, coarse, but not very strongly elevated, oblique costellæ; area flattened, narrow, transversely linear-plicate, traversed by a mesial depressed line, and bounded both above and below by a row of tubercles, those of the lower row surmounting a distinct limiting ridge and larger than those of the preäreal costæ opposite whose terminations they are placed; the areal plications, though fine and numerous, are mostly separated by intervals wider than themselves; preäreal surface denticulate-costate, the denticles

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cuneïform, each consisting of a superior, compressed, tuberculiform head and an attenuated cariniform process which dwindles to a point below, crossing the longer and gentler posterior costal slope, but not crossing the fundus of the intercostal valley quite to the base of the comparatively abrupt anterior costal face. The costæ are moderately interspaced, becoming rather widely intervaled when the shell attains the adult size. A small flattened tract formed by the conjoined antero-dorsal margins, is minutely wrinkled transversely to the margins, as the earlier ribs, before reaching the margin, become suddenly reduced and changed to minute linear folds, paralleled in their intervals by similar folds, of which there are two in each interval.

*Measurements.*—Height, about 30 mm.; length, 36 mm.; breadth, 21 mm. One specimen, represented by a considerable part of a right valve, indicates, with a breadth of about the same or a millimeter less, a height and length 2 or 3 mm. greater. Young examples are relatively shorter, or more elevated, one such example having height 20 mm.; length, 20 mm.; breadth, 14 mm.

*Occurrence.*—One and a half miles east of Malone station. About 35 specimens are represented, many of them only by fragments. A crushed specimen from this locality has the costal and areal ornamentation exceptionally well preserved and shows an almost spinous prominence of the denticles. A cast, representing the anterior two-thirds of a right valve on which the costæ are indicated as plain undulations, obtained by Doctor Stanton about 1 mile east of Finlay station, is supposed to belong to this species, but may represent *T. præstriata.*

*Trigonia proscabra* presents points of resemblance especially to two of the sections of its genus, and does not agree entirely with either. It may be regarded as one of the Clavellatæ which, both as to form and preäreal ornamentation, has assumed the habit of a common phase of the Scabræ. In having an ornamented escutcheon it differs from the typical Clavellatæ, though not from the Pseudoquadratæ—which are intermediate between Clavellatæ and Quadratæ. In having the area bounded on each side by a row of tubercles and below by a pronounced limiting ridge it resembles the Clavellatæ.

### TRIGONIA PRÆSTRIATA sp. n.

Pl. X, fig. 7.

Shell small, crescentic-ovate, only moderately inflated; area strongly and closely striated in a direction oblique to its length, bounded below by a rather strongly compressed and prominent limiting ridge or angulation; preäreal ribs about 12 or 14 in number, coarse, remote, and strongly elevated, descending divergently and for the most part

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more or less vertically, and increasing rather rapidly in size from the limiting angulation to the ventral and anterior borders, about twice as wide as the plain, flattish-concave intervals between them, their summits obtuse and strongly and a little obliquely cross-striated in such a manner that the striation is visible if the ribs are viewed tangentially from in front, but invisible if so viewed from behind.

*Measurements.*—Height, 21 mm.; length, 30 mm.; breadth, 10 mm.; approximately.

*Occurrence.*—A single mold, representing the greater part of a right valve in excellent detail, is the type and only known specimen. It was obtained by Doctor Stanton on the east slope of Malone Mountain, near its southern end, 200 or 300 feet above the gypsum bed that there forms the mountain's base. It lacks the escutcheon, the upper part of the area, and the umbonal apex, but the exterior characters of nearly all of the rest of the shell may be readily observed either in the mold or on the gutta-percha squeeze taken from it. The species is referred to the section Scabræ.

### TRIGONIA MUNITA sp. n.

Pl. X, figs. 8–11.

Shell ovate-pyramidal, of medium or rather large size among its congeners, moderately ventricose, rather elevated; valves thick; area strongly flattened, separated from the preäreal surface by a very large and prominent, obtuse, somewhat imbricated radial costa, preceded by a furrow, the areal surface being ornamented with two rather strong, not widely separated, cariniform radial costæ, which are separated from each other by an interval that is rather narrow as compared with that between either costa and the corresponding areal border, and several similar but smaller costellæ or rays, there being at least two such rays in the anterior interval; preäreal surface ornamented with (25 to 30?) strongly and rather abruptly elevated concentric ribs, which resemble low walls, terminate almost abruptly at the preäreal furrow, and are in large part only about half as wide as the flattish-concave intervals between them.

*Measurements.*—These can not be exactly given, owing to the imperfection of the material, but about the following dimensions are apparently indicated in one instance: Height, 70 mm.; length, 75 mm.; breadth, 42 mm. In another the height is about 80 mm.

*Occurrence.*—Represented by three very imperfect specimens and a number of characteristically ornamented fragments. One of the specimens were obtained by Doctor Stanton near the south end of Malone Mountain, west face, near top, and another west of the mountain, about 2 miles west of Malone station. The remainder of the material is from the locality 1½ miles east of Malone station. All of

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the known material represents the adult condition, or at least rather large sizes of the shell, unless the two specimens described under the head of *Trigonia rudicostata* should be interpreted as the young of *T. munita*. This species with the two that follow belongs to the section Costatæ.

### TRIGONIA RUDICOSTATA sp. n.

Pl. XI, figs. 1, 2.

Shell small, ovate-pyramidal, nearly straight (slightly convex) on the postero-dorsal, broadly convex on the ventral, and less broadly so on the anterior side, inflation intermediate in degree; beaks situated at rear limit of the anterior fourth, prominent and acute at the compressed and transversely placed summit, excavated on the posterior side, turned inward and somewhat backward; area nearly flat, shallow-concave on its proximal part, wide, making with the preäreal surface an angle greater than a right angle, and separated from it by a compressed, prominent radial costa, which is larger than any other costa of the shell, the area posterior to this costa being ornamented with 4 or 5 similar but narrower and smaller rays, between each two of which are 3 to 5 still smaller, strongly elevated, linear rays or costellæ, the intercostellar spaces being at least as wide as, or for the most part wider than, the rays themselves, preäreal surface ornamented with about 25 strongly elevated, round-topped ribs which parallel the basal margin and are mostly slightly wider than the intervals between them. There are 7 of the horizontal or concentric ribs in the lower half in one specimen and 10 on the lower 10 mm. in another.

*Measurements.*—Height, 23 mm.; length, 27 mm.; breadth, 16.5 mm.

*Occurrence.*—The two specimens in the collections were obtained 1½ miles east of Malone station.

Although the material thus far available for study indicates between *T. rudicostata* and *T. munita* differences of both radial and concentric ornamentation too marked to be ignored, it is quite possible that new material from localities known or yet to be discovered may show that these differences are due to conditions of age or individual variation; for it is noteworthy that, except the types of *T. rudicostata*, no Costatæ even approaching what we should predicate for the young of *T. munita*, have been found.

### TRIGONIA CONFERTICOSTATA sp. n.

Pl. XI, fig. 3.

Shell small, subtriangular, of the section Costatæ, apparently more elevated than *T. rudicostata;* posterior area costellate with

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linear rays, of which there are 5 to 7 smaller in the shallow-concave interval between each two of the larger; a large radial rib anteriorly limiting the area; preäreal surface ornamented with about 40 strongly elevated concentric ribs which are much finer than those of *T. rudicostata* and between one and a half times and twice as numerous, and are separated by intervals prevailingly narrower than themselves. In a specimen smaller than the largest, but which nearly corresponds in size with the type of *T. rudicostata*, there are 15 ribs on the lower 10 mm. of height of the valve, as compared with 10 on the same part of the height in the said example of *T. rudicostata.* As against 7 ribs included in the lower half of *T. rudicostata*, there are in one specimen of *conferticostata* not less than 12, and in another 14 in the corresponding half.

*Measurements.*—The dimensions can not be accurately given. The height of the largest specimen is about 33 mm. An apparently crushed and abnormally elongated specimen gives approximately: Height, 25 mm.; length, 29 mm.; breadth, 15 mm.

*Occurrence.*—The species is represented by one nearly complete shell, two considerable portions of valves, and a few fragments; from locality 1½ miles east of Malone station. The shell fragment collected in 1895 by the Messrs. Goodell, and which I referred to in volume 5 of the Journal of Geology (p. 817) as "possibly a Trigonia of the section Costatæ," is of this species.

## ASTARTIDÆ.

### Genus ASTARTE Sowerby.

#### ASTARTE BREVIACOLA sp. n.

Pl. XI, fig. 4.

Cf. *Astarte microphyes* Felix, 1891, Beitr. Geol. u. Pal. Mex., pt. 3, p. 179, Pl. XXVII, fig. 31.

The locality 1½ miles east of Malone station yielded frequent examples of this fossil. They agree fairly well with Doctor Felix's description of *Astarte microphyes*, but not with his figure. As regards the peculiar disposition of the ribs which is given for *A. microphyes*, the tendency to posterior angular bending is well shown in most specimens of the Malone Astarte, but a tendency to anterior angular bending is little or in some cases apparently not at all expressed. If the Cerro de Titania and the Malone specimens are referable to one and the same species, *microphyes*, as seems hardly possible, the form of that species is not quite correctly shown in the original figure, as the anterior part of the dorsal line, instead of sloping like the posterior part, is strongly excavated just in front of the beaks in all of the Malone specimens in which this part of the

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shell is shown. The triangular-ovate to quinquelateral outline presents dorsally a nearly straight incline back of the beaks and is strongly excavated in front of them; has a long, gently convex base, and is posteriorly or infero-posteriorly truncate, and narrowly rounded anteriorly. The shell is quite strongly compressed, and the ribs of either valve reach 11 in number. The ribs are coarse, strongly elevated, gently compressed, and separated by round-bottomed intervals a little wider than themselves. Of more than 60 specimens collected from east of Malone, a single one, among the young examples, is quite ventricose, gapes slightly in the interval between two of the subdistal ribs, and exposes there a double and interlocking set of strong denticles like those of the internal margins of the adult shell.

*Measurements.*—The specimen figured has the following dimensions: Height, 10 mm.; length, 14 mm.; breadth, 4 mm. In less perfect examples a height of 12 mm. and a length of 16 mm. are indicated.

### ASTARTE MALONENSIS Cragin.

Pl. XI, figs. 10, 11; Pl. XII, figs. 1–3.

*Venus malonensis* Cragin, 1893, Fourth Ann. Rept. Geol. Survey Texas, pt. 2, p. 216, Pl. XXXV, figs. 1 and 2; and Jour. Geol., vol. 5, p. 817.

Shell rather large, thick-valved, moderately ventricose, or sometimes slightly compressed, inequilateral, broadly and variably subovate; the dorsal side flattish-convex behind the beaks and excavated in advance of them; the anterior side rounded or slightly subtruncate from being a little prominent in its upper part; the posterior side rather narrowly convex; the base broadly convex; beaks only moderately elevated, approximate, their summits varying from subcentral to a position just back of the anterior third; lunule and escutcheon deeply and abruptly impressed, especially the former, which is narrow-cordate; cardinal teeth 2–2, unstriated, the central of the right valve being much larger than the anterior and the posterior of the left valve being larger than the central;[a] a posterior remote, horizontal, pliciform lateral tooth in either valve fitting into a corresponding groove in the other; pallial line sinuate, its impress on the best-preserved casts crossed by faint radial plications; pallial sinus ample, its anterior and posterior limbs, respectively, subvertical and subhorizontal (the latter a little ascending), its fundus obtuse; valve margins crenulated within; shell ornamented with numerous subequal to unequal concentric, coarsely linear pliciform growth lines, whose sequence is usually interrupted by remote and more elevated folds,

[a] The cardinal teeth are here regarded as 3 in each valve, but with 1 in each valve obsolete.



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imbrications, or constrictions that tend to mark off the surface into regular stages.

*Measurements.*—The type measurements—height, 72 mm.; length, 83 mm.; breadth, 55 mm.—are those of a rotund-ovate example. The height is often somewhat less in proportion to the length. Adult specimens of average inflation have the breadth equal to about two-thirds of the height. The maximum known size is indicated by an imperfect specimen, which has a height of 79 mm.

*Occurrence.*—This is one of the commonest and most conspicuous of the fossils of the Malone formation. It ranges through all of the fossiliferous part of the Theta subdivision that is exposed in the Malone hills, occurring not only at the principal collecting ground, a mile and a half east of Malone station, but also west of the Trio. About 90 specimens were collected at the former locality. Examples were obtained from the west side of the north end of Malone Mountain, at the same horizon and locality that yielded the specimens of Nautilus; from the first high ridge west of Malone Mountain, about 2 miles west of Malone station, and from a locality about 1 mile east of Finlay station. A probable example was obtained by Doctor Stanton from the western foothills, 2 miles north of the southern end of Malone Mountain, and a distorted one was found by me on the anticline in the east side of the mountain, about a mile from its southern end.

Rotund-ovate, transverse-ovate, and oblique or rhombic-ovate are all more or less closely approached by the lateral profile of this shell as preserved, which also in some cases is nearly equilateral. A part of this variation, but evidently not all of it, is to be attributed to the dynamical stresses to which the Malone rocks have been subjected. In young examples the form is usually more oblong, less equilateral, and less compressed, and the concentric ribbing becomes more pronounced and regular, approaching the type of ornamentation commonly seen in medium-sized and small species of Astarte.

The species seems to be sufficiently near the Jurassic section, Cœlastarte, of Böhm.[a] It differs from *Astarte excavata* Sby., the best known representative of that section, in being less strongly inequilateral and in having none of the cardinal teeth striated. The central cardinal of the right valve, while it is the largest tooth of the shell, is relatively smaller than that of *A. excavata* as figured by Böhm. In form it approaches the sinupalliate species *Astarte neocomiensis* d'Orb, from which it differs by hinge details and its crenulated margins.

Stoliczka[b] observes:

[a] Cœlastarte und Heteropis, Ber. Naturf. Ges. Freiburg, i. B. Bd. 7, 1893, pp. 169–178, Pl. VIII.

[b] Cret. Pelecypoda of Southern India, p. 285. Memoirs of the Geological Survey of India. Palæontologia Indica, vol. 3, Calcutta, 1871.

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Eriphyla especially seems to be largely represented among the fossil Astarte, as recorded at the present time, and probably all the species which have an indication of a posterior pallial sinus belong to the former genus. They can scarcely be referred to Astarte, for the single anal opening which the animal of this last possesses lies behind the posterior muscular scar, but not below it, where the formation of a sinus, if present, must be due to the development of muscles supporting a branchial siphon, or at least a special branchial opening. Neither of these are, however, present in Astarte.

But so gradual is the transition from none to a well-marked pallial sinus that it seems impossible in practice to distinguish Eriphyla from Astarte clearly by this criterion.

### ASTARTE POSTICALVA sp. n.

Pl. XI, figs. 5, 6.

Shell small, thin, triangular-ovate, of intermediate convexity; beaks rather prominent and pointed, directed somewhat forward, anteriorly excavated, placed near and usually back of the limit of the anterior third; posterior slope a little flattened; anterior three-fourths (to four-fifths) of shell ornamented with numerous linear concentric costellæ, which are separated in strong relief by deep striæ about half as wide as themselves; the flattened posterior fourth or fifth forming a sort of area which is plain, or marked with ordinary growth lines only, and is separated from the preäreal surface by a very obtuse or rounded radial angulation which is not of itself a discrete and salient feature, but consists merely of the rather abruptly curved transition from the outer to the flattened posterior slope of the shell. The costellæ are deflected at their posterior ends, vanishing rather rapidly, but not abruptly, as they approach the plain area.

*Measurements.*—Height, 13 mm.; length, 15 mm.; breadth, 10 mm. A valve of another specimen has a height of about 14 mm. and a length of 17 mm.

*Occurrence.*—Not infrequent 1½ miles east of Malone station. Twenty-one specimens were collected.

### ASTARTE? ISODONTOIDES sp. n.

Pl. XI, figs. 8, 9.

Shell small, gibbous, inequilateral, oblong-ovate, the dorsal line gently declivous and slightly convex back of the beaks and very feebly excavated in front of them; base nearly straight; anterior side rounded; posterior side obliquely truncated; beaks low, in contact, situated near the anterior third, an obtuse umbonal ridge or inflation extending from their summits to the postero-ventral margin, and the greatest breadth of the shell being, by reason of such infla-

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tion, near the anterior limit of the posterior third; flanks and postumbonal slopes more or less flattened; ligament external, short; surface of shell concentrically striate, or ornamented with numerous strong linear elevations whose development varies, and is more regular on the proximal part of the shell, while on the distal part there are one or two excavated zones bounded by high lines. The lines run nearly straight for a considerable part of their course parallel to the base, turning upward more shortly at the posterior than at the anterior end of it.

*Measurements.*—Height, 13 mm.; length (restored), about 18 mm.; breadth, 10 mm.

*Occurrence.*—A mile and a half east of Malone station. Only 1 specimen of the typical form was obtained. Of 3 others believed to be only young and compressed examples of the species, 2 are more or less complete right valves, 1 of which shows a ligamental groove and a strongly denticulated inner margin; and the third is a shell quite flattened out. All three of these young examples agree with the proximal and differ from the distal part of the type shell in having a tendency to a rather uniform and close development of the concentric linear costellæ.

The specific name refers to some resemblance which the shell presents in form to that of Isodonta, as represented by the type of that genus, *I. deshayesii* Buv.

### ASTARTE? CRATICULA sp. n.

Pl. XI, fig. 7.

Shell small, rather ventricose, subovate, strongly depressed along a narrow zone near the posterior cardinal border from the beaks to the posterior extremity; beaks well inflated, moderately elevated, placed somewhat in advance of the middle and back of the anterior third; postero-dorsal flattened area separated from the rest of the shell by a radial angulation and itself divided into two concave zones by a radial cariniform angulation; the general surface of the valves ornamented rather closely with regular, blunt-topped, concentric costellæ, which are in strong relief and separated by intervals of about their own width. The ornamentation of this shell recalls the genus Trigonia.

*Measurements.*—Estimated measurements only can be given, the margins of both valves of the type being imperfect. The apparent approximate dimensions are: Height, 22 mm.; length, 28 mm.; breadth, 17 mm.

*Occurrence.*—The only specimen obtained is from the locality 1½ miles east of Malone station.

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## CRASSATELLIDÆ.

### Genus PTYCHOMYA Agassiz.

#### PTYCHOMYA STANTONI sp. n.

Pl. XII, figs. 4–6.

Shell small, compressed, cuneate-ovate or trapezoid-ovate, a little excavated at the front of the beaks; the anterior side short, rounded; the posterior side long; the dorsal margin having a gentle and nearly straight descent back of the beaks for a considerable distance and then declining more rapidly, so that the posterior side of the shell is obliquely truncate above; the base nearly straight in its median and major portion; the posterior umbonal slope forming with the outer slope a gentle shoulder; valves thick, their margins crenulated within: beaks very little salient; lunule cuneate-lanceolate, deeply excavated; surface ornamented with a considerable number of ribs which form an anterior nearly vertical series of upwardly directed chevrons below the beaks, and a posterior oblique series of nearly closed, distally directed angles whose apices lie on the umbonal shoulder; on the posterior part of the shell the ribs pursue a nearly straight course backward and downward to the basal and posterior margins, though arranged in two converging sets, in each of which they are slightly divergent; on the anterior region they are subhorizontal, curved forward and upward, and often minutely undulated or zigzagged. The sides of the subumbonal chevrons, exclusive of the part that forms the usually more or less cuspidate apex, diverge at an angle which is right or sometimes slightly acute in the earlier ribs and becomes quite obtuse in the later ones. The ribs are generally linear-compressed and separated by broader concave intervals, but in occasional specimens, and especially on the posterior region, are more obtuse, with the intervals equaling or distally exceeding them.

*Measurements.*—A nearly complete right valve indicates: Height, 16.5 mm.; length, 31 mm.; breadth, 8 or 9 mm. An internal cast of a right valve gives: Height, 18 mm.; length, 32 mm.

*Occurrence.*—Twenty-three specimens, in part only fragments, with the characteristic ornamentation, are in hand. All are from the locality 1½ miles east of Malone station, and most, if not all, from the lower part of the Theta beds there outcropping.

In pattern of ornamentation and in size *Ptychomya stantoni* comes nearest to *Pt. complicata* Tate, from which it differs in having the beaks less anteriorly placed and the posterior truncation very oblique instead of nearly square; the position of the beaks and the line of chevrons below them is as in *Pt. koeneni* Behrendsen. The general form has some resemblance to the latter species, but its lateral profile departs more from a regular oval and tends toward a cuneate. It

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differs from *Pt. koeneni* also by its much smaller size, and in the absence of small downward-pointing chevrons at the apices of the middle and lower of the large upward-pointing ones.

The species is named after Doctor Stanton, who first recognized its genus on seeing it in my collection at Sierra Blanca, Tex., he having previously ascertained that *Pholadomya ragsdalei* Nobis belongs also to Ptychomya. Doctor Stanton has recently shown me two casts of the latter species on which the hinge characters of the left valve, as described and figured by Pictet and Campiche,[a] are well displayed.

The Ptychomyæ hitherto described, so far as known to me at this time (1899), are as follows:

*Ptychomya robinaldina* (d'Orbigny), 1843, Pal. Fr., Terr. Cret., vol. 3, p. 75, pl. 264, figs. 10–13.

*Ptychomya solita* (d'Orbigny), 1851, Rev. et Mag. de Zoöl., 2d series, vol. 3, p. 381, pl. 10, figs. 3, 4.

*Ptychomya* sp. Unnamed. Described and figured, 1857, by Pictet and Renevier in Pal. Suisse, Terr. Aptien de la Perte du Rhône, et Ste. Croix, p. 90, pl. 11, figs. 2a, 2b, 3a, 3b, as of *Pt. robinaldina* (d'Orb.), but removed from the latter by Pictet and Campiche in 1866 (Pal. Suisse, Foss. Terr. Cret. Ste. Croix, p. 357), and placed near *Pt. neocomiensis* (de Loriol) either as a variety of the latter or a distinct species.

*Ptychomya buchiana* (Karsten), 1858, Geognost. Verhältn. des Westl. Columb., Bericht 32 ste Versamml. Deutsch. Naturf. u. Ärtze, p. 113, Pl. V, figs. 7a, 7b.

*Ptychomya neocomiensis* (de Loriol), 1861, Descr. des Anim. Foss. du Mont Salève, p. 71, pl. 9, figs. 1–4.

*Ptychomya dædalea* Coquand, 1866, Mon. Pal. de l'Étage Aptien de l'Espagne, p. 127, Pl. XX, figs. 1, 2.

*Ptychomya germani* Pictet and Campiche, 1866, Pal. Suisse, Terr. Cret. de Ste. Croix, p. 354, Pl. CXXVII, figs. 7, 8.

*Ptychomya complicata* (Tate), 1867, Quart. Jour. Geol. Soc. London, vol. 23, Pt. I, p. 160, Pl. IX, fig. 8.

*Ptychomya zitteli* Dames, 1873, Zeitschr. Deutsch. Geol. Gesellsch., vol. 25, p 380, Pl. XII, figs. 1, 2.

*Ptychomya sp.* Unnamed. Described and figured, 1882, by Franz Toula in Denkschr. Kais. Akad. Wissensch. Mat.-Nat. Cl., Bd. XLIV, 2te Abth., p. 35, Pl. IV, fig. 18. Regarded by Toula as probably identical with *Pt. neocomiensis*, though he notes differences. It seems to me to be separated by its strongly arched principal costæ and dorsal border, as well as by its size.

*Ptychomya koeneni* Behrendsen, 1892, Zeitschr. Deutsch. Geol. Geselsch., vol. 44, p. 23, Pl. II, fig. 4, and pl. 3, figs. 8a, 8b.

*Ptychomya ragsdalei* (Cragin), 1895, Colorado College Studies, V, p. 58.

In addition to the above, a species of Ptychomya has been reported by G. Steinmann[b] as occurring in the Cordilleras at Chillan, Chile, possibly in the same bed with *Trigonia transitoria* Steinmann. This Trigonia occurs also at Caracoles, Bolivia, from an unknown horizon

[a] Pal. Suisse, Terr. Cret. de Ste. Croix, p. 351, Pl. CXXVII, figs. 9d, 9e.

[b] Neues Jahrbuch f. Min., etc., 1882, vol. 1, p. 224.

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that, on the ground of the kind of rock attached to the specimen, Professor Steinmann regards as probably Lower Cretaceous, though nearly all of the Mesozoic fossils that he lists from Caracoles he considers Jurassic. I am not aware that the Chillan Ptychomya has been specifically named or described.

The orbicular, toothless, divaricately ornamented shell described by Lycett[a] as *Ptychomya? agassizii*, and the elongate *Pandora? æquivalvis* Deshayes[b] and *Crassatella cornueliana* d'Orb.[c] which have been referred to Ptychomya by some paleontologists, are here, following Stoliczka,[d] excluded from the genus.

The size of the shell in Ptychomya seems to have been less in the earlier history of the genus and to have reached its maximum in the Gault. The relation of size to time is indicated in the following table, in which an attempt has been made to group the species roughly in accordance with their relative geological position, known or supposed:

*Table showing sizes of species of Ptychomya at various geological epochs.*

| Species. | Length. | Geological position. | Locality. |
|---|---|---|---|
| | *mm.* | | |
| zitteli | 90 | Turonian | Western Alps. |
| ragsdalei | 105 | Upper part of Denison stage | Northern Texas. |
| buchiana | 120 | Gault | United States of Colombia. |
| dædalea | 110 | Aptian | Spain. |
| (Unnamed) | 80 | Aptian | Switzerland. |
| solita | 80 | (? Upper part of) Lower Cretaceous | United States of Colombia. |
| (Unnamed) | 67 | Uppermost Neocomian (probably fide Toula). | Western Balkans. |
| neocomiensis | 60 | Lower and middle Neocomian | France, Switzerland. |
| koeneni | 57 | Neocomian[e] | Argentine Cordilleras. |
| robinaldina | 35 | Lower and middle Neocomian[f] | France, Switzerland, England. |
| germani | 40 | Lower Neocomian (Valangian) | St. Croix, Switzerland. |
| complicata | 31.7 | Lower Neocomian? (Jurassic?) | Cape of Good Hope. |
| stantoni | 32 | Malone | Southwestern Texas. |

[a] Proc. Cotteswold Naturalists' Club, vol. 1, p. 69, Pl. 11, figs. 6, 6a.

[b] Mem. Soc. Géol. de France, vol. 5, p. 4, pl. 3, figs. 7a, 7b.

[c] Pal. fr., Terr. Crét., vol. 3, p. 74, pl. 264, figs. 7–9.

[d] See Cret. Fauna Southern India, vol. 3, p. 294.

[e] Behrensden compares his species with the lower and middle Neocomian species, *germani* and *robinaldina*.

[f] Morris and E. Forbes have recorded this species from the lower Greensand; but these records are early ones (1845 and 1854) and not improbably refer to *Pt. neocomiensis*, which was not established till 1861. A species close to *Pt. neocomiensis*, and perhaps not specifically distinct from it, was referred to *robinaldina* by Pictet and Renevier as late as 1857 to 1866. See remarks in above list of hitherto-described Ptychomyæ.

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## LUCINIDÆ.

### Genus LUCINA Brug.

#### LUCINA POTOSINA C. and A.

Pl. XIII, figs. 4, 5.

*Lucina potosina* Castillo and Aguilera, 1895, Bol. Com. Geol. Mex., No. 1, p. 6, Pl. IV, figs. 2, 3, and 6; and Pl. V, figs. 11 to 14.

Five specimens from the locality 1½ miles east of Malone station seem to agree sufficiently well in size and form with the small, transverse and rather inflated Sierra de Catorce shells that constitute the type variety of *Lucina potosina*.

The following is a translation of Castillo and Aguilera's description of the species:

Shell transversely oval, relatively compressed, inequilateral. Buccal region longer than the anal, uniformly rounded at its extremity and nearly of the same width as the anal. Lunule well developed, rather deep and generally wider in the right valve. Anal region nearly of the same breadth as the buccal, rounded at its extremity, more inflated than the buccal region. Ligamental area narrow, deep, and elongated, occupying the whole length of the anal region. Cardinal border slightly concave on the buccal side and straight or gently convex on the anal side. Umbones subcentral, contiguous, and a little inclined to the buccal side. Ventral or lower border little curved, joined to the anterior and posterior borders by arcs of more pronounced curve than its general curvature. Flanks convex, more inflated below the beaks where the major convexity is found; this diminishes gradually toward the borders. Surface adorned with delicate concentric costellæ, little salient and separated by plain intervals four to six times wider than the costellæ. Length, 19, 20.5, 21 mm.; breadth, in relation to the length, 0.79, 0.80, 0.85; thickness, in relation to the length, 0.47, 0.48, 0.48.

The exact geological position of *Lucina potosina* at its type locality is not known, as the records are somewhat conflicting. Castillo and Aguilera state, on page 8 of the above-cited bulletin, that the types of this species and of *Cyprina coteroi* were found associated with Alamitos fossils, but were petrified in flint, believed to have been derived from the flint-bearing limestones of their "grupo superior," that overlie the sandstones of the Cieneguita (Lower Cretaceous) as the Cieneguita in turn overlies the Alamitos (Upper Jurassic). On page 49 of the same they omit *Cyprina coteroi*, but include *Lucina potosina* in the list of fossils of the grupo superior, and state that *Schloenbachia af. inflata* is the only fossil found in the limestones of the grupo superior, ascribing *Lucina potosina* and the other fossils of the grupo superior to calcareous and marly shale below the limestone, in the base of the grupo. Finally, on page 50, *Cyprina coteroi* is given as one of the fossils of the Alamitos beds, which are Upper Jurassic. In view of the confusion that has arisen regarding the original stratigraphic source of these fossils, and the further fact that the actual collecting of them seems to have been from among the fossils of the Alamitos, there would appear to be some uncertainty as to their

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having come from the flint-bearing limestones of the grupo superior, notwithstanding the flinty character of their fossilization and a possibility, at least, that both species may have come from some minor intercalation or segregation of siliceous matter in either the Cieneguita or the Alamitos beds.

### LUCINA POTOSINA var. METRICA var n.

Pl. XIII, figs. 6–10.

*Lucina metrica* Cragin, 1898, Jour. Geol., vol. 5, p. 817.
*Lucina potosina ?* Cragin, 1898, loc. cit., p. 817 (footnote) and p. 819.

Shell equivalve, compressed or little inflated, flattish-lenticular, suborbicular, yet tending somewhat to a four- or five-sided outline, usually a little transverse, but often not markedly so, sometimes about equilateral, for the most part slightly, and in exceptional cases considerably, inequilateral; valves thin; postero-dorsal region somewhat especially compressed in contrast with the gently inflated umbonal region in front of it, the concavity here being counterbalanced by a feebler compression of the antero-dorsal region; beaks very small and depressed, subcentral, usually placed a little back of the middle; surface ornamented with widely and regularly interspaced, strongly and abruptly elevated, linear-compressed, concentric costellæ. The spaces between the latter are about six times as wide as the costellæ themselves, flat, marked only with numerous and fine crowded, concentric growth lines; and are remarkable for the regularity of their breadth, which increases distally with almost imperceptible increments, but shows occasional variations.

*Measurements.*—Height, 34 mm.; length, 35 mm.; breadth, 10 mm. in a specimen of the commoner and intermediate size, much smaller specimens being similarly proportioned. For the same dimensions, an example of average adult size and an exceptionally large one give, respectively, 41, 45, 14, and 54, 59, 16 mm.

*Occurrence.*—A mile and a half east of Malone station. One of the more abundant fossils there occurring, but less common than the *Pleuromya inconstans*. More than 200 specimens are represented. A few examples were also obtained in foothills at the northwest end of Malone Mountain, about 2 miles east-southeast of Finlay station, and west of the mountain, 2 miles north of its southern end.

The height of the shell in *L. potosina*, var. *metrica* is commonly from 90 to 97 per cent of the length, which, however, it may occasionally equal. The breadth averages less than 30 per cent of the length; in 10 measured specimens it averages 29.46, the minimum being 25.5, and the maximum being 32 per cent. The corresponding ratios given by Castillo and Aguilera for typical *potosina* are height as percentage of length 0.79 to 0.85, and breadth as percentage of length 0.47 to 0.48.

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From all of the data above given it is seen that the shell of var. *metrica* attains a much larger size than that of var. *potosina*, is considerably less inflated, and has a less transverse (i. e., more elevated) and more nearly equilateral contour.

*Lucina potosina*, var. *metrica* is not only a pronounced variety of its species but it is the largely preponderating representative both of its species and of its genus in the Upper Jurassic of western Texas.

As is usually found to be the case where very large numbers of a species of fossil are available for study, *L. potosina* presents considerable individual variation. Seven or eight specimens from locality 1½ miles east of Malone, represent a third variety of the species, which is apparently only an individual phase, though rather a striking one, of var. *metrica*. They show the following characters: The shell is about as large as the largest examples of the ordinary form of *metrica;* transversely broad-oval, inclining to subquadrate; inequilateral; inflated throughout, though unequally so, the valves being radially warped or flexuous, and especially swollen on the umbonal slope, on either side of which are two broad and shallow concave radial zones, the anterior one of which passes downward and the posterior one downward and backward; a second and smaller convex radial zone being developed in front of the anterior concave one. The beaks are more inflated than those of the typical form of var. *metrica*. The basal margin of the shell is a little prominent and receding opposite the convex and concave zones, respectively. Corresponding with the general contour of the shell, the concentric linear costellæ, which in the common phase of var. *metrica*, have an almost uniform downward convexity in the postero-basal part of their course, assume in this phase a nearly straight or slightly upward convex trend for a considerable distance in this part of their course, swinging upward rather suddenly anterior and posterior to it. The approximate dimensions are: Height, 45 mm.; length, 50 mm.; breadth, 20 mm.

This phase, then, is distinguished from the ordinary phase of var. *metrica* by its size, average adult examples of the latter being considerably smaller, by its greater and more pervasive inflation, strongly flexuous valves, and more transverse and inequilateral contour. A tendency toward this form is seen in some of the smaller examples of the other phase of *metrica*.

### LUCINA ? EMARGINATA sp. n.

Pl. XIII, figs 1, 2.

Cf. *Cyprimeria ? mexicana* Castillo and Aguilera, 1895, Bol. Com. Geol. Mex., No. 1, p. 9, Pl. V, fig. 3.

Shell suborbicular, compressed, though less so than that of *Lucina potosina*, var. *metrica*, the breadth being equal to about half of the

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height; anterior, ventral, and posterior sides rounded; dorsal side abruptly and emarginately excavated before the beaks to a point distant one-fourth of the shell length, where it joins the anterior side in an obtuse angle, the posterior part of the dorsal side declining in a nearly straight line, with some convexity near the beaks, to a point two and a half times as remote, where it makes an obtuse angle with the posterior border; beaks low, with apex curved forward; lunule large, about twice as long as wide, abruptly and rather deeply impressed; margins entire; surface ornamented with rather coarse, rounded, subdued, concentric costellæ separated by equal or narrower intervals, each costella making an irregular and gentle undulatory flexure as it approaches the posterior part of the dorsal margin.

*Measurements.*—In an accidentally somewhat compressed specimen, height, 21 mm.; length, 22 mm.; breadth, 7 mm. In a second example, height, 20 mm.; length, 19 mm.; breadth, 10 mm. In a third, height, 32 mm.; length, 30.5 mm.; breadth about 16 mm.

*Occurrence.*—Three examples were obtained from the locality 1½ miles east of Malone station.

In the absence of a satisfactory knowledge of the hinge details, the species is here placed in the genus *Lucina* because of the abruptly excavated and rather deep lunule, the lunule in *Cyprimeria* being feebly excavated or lacking.

### LUCINA PLANIUSCULA sp. n.

Pl. XIII, fig. 3.

Shell of intermediate size for *Lucina*, thick-valved, broadly suboval, rather inflated, the breadth equal to more than half of the height, height equaling about five-sixths of the length, moderately inequilateral, the posterior side being between three-fourths and four-fifths as long as the anterior, the latter but little contracted; beaks little prominent; surface nearly plain, ornamented with inconspicuous, concentric raised lines and striæ, which on the major part of the surface are more or less obsolete, but are more distinct on the anterior and posterior marginal regions, the raised lines on the latter being very fine and intervaled on the upper part, becoming coarser and more crowded below.

*Measurements.*—Height, 26.5 mm.; length, 31 mm.; breadth, 15 mm.; in another example, height, 28 mm.; length, 31 mm.

*Occurrence.*—Four shells and about a dozen casts of this fossil were collected in foothills in the northwest end of Malone Mountain, about 2 miles east-southeast of Finlay station.

From *Lucina coetoi* C. and A., the *L. planiuscula* appears to differ chiefly by its more strongly inflated and much less strongly inequilateral shell and its plainer ornamentation.

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## Genus UNICARDIUM d'Orbigny.

### UNICARDIUM ? SEMIROTUNDUM sp. n.

Pl. XII, figs. 9–11.

Shell thin, pyramido-suborbicular, moderately inequilateral, well inflated, the height nearly equal to the length; beaks large and prominent, pyramidal, submedian, placed a little nearer to the anterior than to the posterior extremity, curved inward and slightly forward, so that the anterior cardinal border is more concave than the posterior; anterior and posterior borders rather short; base evenly and rather broadly rounded; surface marked only with fine concentric growth lines, most of which are rather feebly, a few more strongly, impressed.

*Measurements.*—Height, 21 mm.; length, 22 mm.; breadth, 13 mm. Height in another nearly like-proportioned example about 25 mm.

*Occurrence.*—Twelve specimens were collected by Doctor Stanton at the following four localities: A mile and a half east of Malone station; anticline in east base of Malone Mountain about 1 mile north of its southern end; west of Malone Mountain, nearly 2 miles south of west from Malone station, in No. 13 of his Malone Mountain section; and in foothills at the northwestern end of Malone Mountain, a little over 2 miles east-southeast of Finlay station, here also apparently in No. 13. Four examples were also collected by me at the first of the localities above named.

The species shows some resemblance in form to *U. variçosum* Sowerby, but has larger and more elevated umbones and, for the body of the valves, a more rotund contour.

### UNICARDIUM ? TRANSVERSUM sp. n.

Pl. XII, figs. 7, 8.

Shell thin, well inflated, transversely subovate, the height equaling 0.77 to 0.87 of the length; the posterior moiety of the shell narrower and considerably longer than the anterior, and the anterior part of the cardinal border more concave than the posterior; base broadly and unequally rounded; beaks prominent, yet less so than those of *Unicardium semirotundum*, in contact; surface smooth, marked only with fine concentric growth lines, which disappear under slight weathering. While the form of the shell is persistently transverse or subovate, the position of the beaks is widely variable, as shown by the umbonal fractions below, in which the numerator and denominator, respectively, denote the distances in millimeters of the umbonal summits from the anterior and posterior ends of the shell in four specimens selected at random. That this variability, how-

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ever, is in part due to the orogenic movements which the matrix has undergone is indicated both by other variation in the form and by the discrepancy sometimes shown in the relative position of the two beaks of a single shell.

*Measurements.*—Height, 26 mm.; length, 34 mm.; breadth, 21 mm. Same dimensions from a left valve, respectively; height, 24 mm.; length, 29.5 mm.; breadth (by doubling the convexity of one valve), 15 mm. Umbonal fractions, $\frac{13}{18}$, $\frac{25}{42}$, $\frac{14}{17}$, $\frac{10}{13}$.

*Occurrence.*—Fourteen specimens were collected from the locality 1½ miles east of Malone station; one from the anticline on the eastern slope of Malone Mountain nearly 1 mile north of the southern end; and one also upward of 1 mile east of Finlay station.

## CYPRINIDÆ.

### Genus CYPRINA Lamarck.

#### CYPRINA COTEROI C. and A.

Pl. XIII, figs. 11, 12.

*Cyprina* (*Venilia*) *ceterot* Castillo and Aguilera, 1895, Bol. Com. Geol. Mex., No. 1, p. 8, Pl. V, figs. 4 to 10.

Shell thin, triangular-ovate, inequilateral, ventricose, the height generally equaling one and a third to nearly one and a half times the breadth and about seven-eighths of the length; posterior slope flattened and separated from the rest of the shell by a low crest, or angulation, which runs from the posterior side of the beaks to the somewhat pointed infero-posterior end of the shell; beaks situated between the middle and the anterior third, strongly inflated, high arched, pyramidal, incurved, somewhat anteriorly deflected, and nearly, if not quite, in contact; pallial line entire; general surface ornamented with ordinary concentric growth lines and at remote intervals with resting stages marked by moderate imbrication and groove, which descend across the posterior flattened area and turn suddenly forward at the posterior angulation.

*Measurements.*—Height, 34 mm.; length, 41 mm.; breadth, 27 mm.

*Occurrence.*—Four (and two doubtful) specimens, from locality 1½ miles east of Malone station.

There is some doubt as to the true horizon of the type specimens of this fossil. See remarks as to same on page 72, under *Lucina potosina*.

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## CYPRINA? STREERUVITZII Cragin.

Pl. XIV, figs. 1, 2; Pl. XV, fig. 1.

*Cyprina (Roudairia?) streeruvitzii* Cragin, 1893, Fourth Ann. Rept. Geol. Survey Texas, pt. 2, p. 180, Pl. XXXVI, figs. 3 to 5, and Pl. XL, fig 2.

*Cyprina streeruvitzii* has been found only in the Theta, and can hardly be called an abundant fossil. Notwithstanding its large size and the fact that special search was made for it at its type locality, 1½ miles east of Malone station, the most prolific lamellibranch field known in the Malone formation, only 11 incomplete specimens and casts were found, and none of these is as good as the specimen collected there by Mr. Wyschetzki, the topographer of Mr. Von Streeruwitz's party, in 1890. They were all, or nearly all, obtained from the west slope of the Truncate mound.

They add little to our knowledge of the species.

The cast, owing to its narrow, very elevated, and strongly arched beaks, bears considerable resemblance to that of *Cyprina texana* Conrad. Its posterior area is outwardly bounded by an obtusely compressed, prominent ridge, interior to which is a round-bottomed sulcus, followed by another radial elevation and depression within. The casts of the anterior adductor scar are exceedingly prominent. An undersized though apparently normally proportioned cast has the height 73 mm.; breadth, 64 mm., and length approximately 80 mm. The largest example of the shell has the beaks broken off, but has a length of about 124 mm. Another specimen of the shell presents a height of about 106 mm.

Attached to some of the specimens by the stony matrix are characteristic parts of *Trigonia vyschetzkii*, *T. proscabra*, *Lima interlineata*, *Astarte breviacola*, *Mytilus nuntius*, *Serpula gordialis*, and other fossils.

There remains some doubt as to the genus of this shell, as the hinge characters have not been observed. The following is the original description of the species:

Shell large, triangular, the anterior and posterior sides of the outline being subdirect, the basal convex, height and length of shell about equal, exceeding the breadth; beaks prominent, situated somewhat in advance of the middle, posteriorly flattened or concave, their summits turned inward and forward till tangent or subtangent above the downward, outward, and backward curled apices, the latter overhanging a large and deeply impressed heart-shaped lunule, which is higher than wide, and is bounded by a moderate slope, the margins of the valves immediately below the lunule forming no such keel as is seen in *Cyprina roemeri*, the anterior termination of the shell being, on the contrary, very obtuse; posterior slope in either valve bicarinate, having, in addition to the primary angulation which abruptly separates the discal from the posterior slope, a second and similar radial angulation at a position which is at

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first about two-thirds of the distance from the primary angulation to the posterior shell-margin, and which at length reaches that margin at rather more than two-thirds of the distance from the beaks to the distal extremity of the primary angulation; intercarinal areæ concave, that included by the secondary carinæ forming an escutcheon, those included between the primary and the secondary carinæ continuous with the posterior flattening of the umbonal summits; entire exterior of the shell presenting numerous strong concentric growth lines and divided off on the disk into rather broad, subequal, concentric zones by narrow, low, and, in part, obsolescent concentric ribs. Valves thick.

*Measurements.*—Height, 88 mm.; length (approximately), 93 mm.; breadth, 74 mm.

## VENERIDÆ.

### Genus TAPES Megerle.

#### TAPES? CUNEOVATUS sp. n.

Pl. XIII, fig. 13.

Shell gently compressed, thin, cuneate-ovate; the convex-tapered posterior side narrowly rounded at the end; anterior side rounded; base gently convex; dorsal margin rather abruptly excavated at front of beaks; breadth contained about one and a half times in height; height about one and a half in length; beaks placed at posterior limit of anterior third; surface finely concentric striate.

*Measurements.*—Height, 17 mm.; length, 24.5 mm.; breadth, 10 or 12 mm.

*Occurrence.*—A mile and a half east of Malone station; represented by a right valve complete as to form, but with the larger part of the shell removed by weathering, enough, however, remaining to show the character of the ornamentation.

## PHOLADOMYIDÆ.

### Genus PHOLADOMYA Sowerby.

#### PHOLADOMYA TOSTA (Cragin).

Pl. XV, figs. 2, 3.

*Anatina tosta* Cragin, 1893, Fourth Ann. Rept. Geol Survey Texas, pt. 2, p. 168.

*Pholadomya tosta* Cragin, 1897, Jour. Geol., vol. 5, p. 817.

Shell large among its congeners, moderately ventricose, very inequilateral, oblong, with rounded extremities and long, straight-convex to feebly sigmoid base, pointed-ovate in cross section; the anterior region short; the posterior region long and somewhat narrowed, its cardinal margin feebly concave; beaks low-arched, in contact, placed at about a fifth (sometimes less) of the shell length from the anterior end; entire shell presenting fine growth lines and irregularly intervaled, coarser, concentric imbrications, which on an anterior small

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and a supero-posterior larger area constitute the only markings, all of the shell except these terminal areas being crossed by radiating ribs, of which there are about 20 on either valve. The ribs are narrowly compressed and rather strongly elevated (cariniform), often with irregularly crinkled summits, and some of them are pressed backward so that the posterior slope is comparatively gentle, while the anterior is steep or overhangs, giving them somewhat the appearance of imbrications; they are unequally remote and separated by broad, flattish-concave intervals; and one of the posterior ribs is usually higher and larger than the others, the two or three that are yet posterior to this, and a few of the anterior ribs, being less pronounced than the others. The anterior part of the base is gently convex, becoming straighter and gradually a little rising posterior to a point between the middle and the posterior end, and again apparently a little descending or prominent opposite the largest one of the posterior ribs, the base describing thus a feebly sigmoid curvature. The latter feature is not seen in all specimens, and may be due to mechanical distortion.

*Measurements.*—The two largest specimens average about 50 mm. in height. The breadth is apparently about three-fourths of the height, and the height about half of the length.

*Occurrence.*—Twenty-five specimens are represented from locality 1½ miles east of Malone station.

### PHOLADOMYA MARCOUI sp. n.

Pl. XVI, figs. 1, 2.

Shell of medium or small-medium size in its genus, very inequilateral, short-oblong or ovate-oblong, more or less rounded at both extremities, ventricose; posterior cardinal border slightly excavated; the posterior region convex-cuneately compressed, gaping narrowly at the upper posterior border; beaks situated near the anterior end, elevated about as in *Pholadomya candida* Sby., or *P. glabra* Ag.;[a] surface, except small anterior and posterior dorsal portions, ornamented with a few (about 6?) remote, feebly expressed, or obsolescent, cariniform, radial ribs, the posterior one of which is directed nearly straight backward (slightly downward), and also unevenly marked with coarse concentric growth lines.

*Measurements.*—Height, 36 mm.; length, 56 mm.; breadth, 32 mm.

*Occurrence.*—A mile and a half east of Malone station. This Pholadomya seems to be less common than either *P. tosta* or *P. dumbli.* Ten examples were obtained.

This or a closely related form was found with *Exogyra potosina*,

[a] Referring here to the species as presented in pls. 108 and 109 of Tryon's Structural and Systematic Conchology.

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etc., at the western base of Malone Mountain, a short distance north of its southern end, the cast bearing indications of feeble ribs about as in *marcoui*, but this form—perhaps modified by orogenic movements of the matrix—being longer, lower, and smaller-calibered than it is normally in the latter species.

The species is named for the late Mr. Jules Marcou.

### PHOLADOMYA PAUCICOSTA Roemer?

Pl. XVI, figs. 5, 6.

*Pholadomya paucicosta* F. A. Roemer, 1836. Versteinerungen des Norddeutschen Oölithgebirges, p. 131, Pl. XVI, fig. 1.

Form stout, curved-cuneate-pyriform; the umbonal region widely inflated transversely to the length of the shell; anterior region shortened almost back to the large, prominently elevated, tangent umbones, which are thus made almost terminal; the anterior margin slightly gaping; posterior region widened in the median plane, compressed, most strongly so in the upper part, which tends to a keel-like form and gapes considerably; base drawn upward rapidly in the anterior part, so that, in connection with the very salient beaks, the whole anterior (including umbonal) moiety of the shell has an upturned appearance; surface ornamented with coarse, unequal, concentric, costelliform growth plications and furrows and apparently with 4 or 5 low folds radiating from the beaks forward and downward to the basal margin.

*Measurements.*—The dimensions can be given only roughly. They appear to average, for the larger specimens: Height, 52 mm.; length, 61 mm.; breadth, 48 mm.

*Occurrence.*—Not rare in the Malone Hills, a mile and a half east of Malone station. Among 26 specimens there collected the mechanical distortion has been such that no two are quite alike. There is, however, a central phase about which they are grouped and to which several of them closely approximate, affording a sufficiently correct idea of the normal form; and so different is the shell from any other found in these beds that it can be recognized in any of its false shapes, though the radial markings are rarely well preserved and often not shown at all. A specimen was obtained by Doctor Stanton near the railroad, about 2 miles east-southeast from Finlay station, in the northwestern foothills of Malone Mountain.

Accepting for the European Upper Jurassic *Pholadomya paucicosta* Roemer, the wide range of specific variation indicated for it by Moesch,[a] it seems impossible to separate the above-described Malone species from it.

[a] Monographie der Pholadomyen. In Abhandl. Schweiz. pal. Gesell., vols. 1 and 2.



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### PHOLADOMYA PRÆPOSITA sp. n.

Pl. XVI, figs. 3, 4.

Shell small for its genus, cuneate-oblong, arched somewhat downward, very broad across the antero-dorsal or umbonal region, the breadth at least equal to the height, convex-cuneately narrowed toward the base and rear; anterior side rather truncate; base gently convex; beaks anterior, terminal, projecting forward a little beyond the rest of the shell, directed forward and upward, then arched strongly inward, the apices curved a little backward, somewhat compressed as if by gentle pressure on the anterior (or inferior) and posterior (superior) sides; surface with faint concentric markings and several remote, low, slender, cariniform costellæ which radiate from the summit of the beaks, the anterior 6 (or more) obliquely crossing the inferior (anterior) umbonal slope to the base. The anterior part of the base is sharply and even a little biconcavely compressed, and a limited anterior region of the shell is free from the cariniform rays.

*Measurements.*—Height, 22 mm.; breadth, 22.5 mm. In a second specimen, height, 20 mm.; breadth, 20 mm. The length of these specimens (at least more than 31 mm.) can not be exactly given, as they are posteriorly broken off. A third, with only remnants of the shell, but nearly normal as to shape, gives, height, 20 mm.; breadth, 20 mm.; length, 34 mm. A fourth example, too much weathered on the flanks to give the breadth, has a height of 24 mm., and a length of 43 mm.

*Occurrence.*—Four examples from locality 1½ miles east of Malone station.

## Genus PLEUROMYA Agassiz.

### PLEUROMYA INCONSTANS C. and A.

Pl. XVII, figs. 1–5; Pl. XVIII, figs. 1–3.

*Pleuromya inconstans* Castillo and Aguilera, 1895, Bol. Com. Geol. Mex., No. 1, p. 10, Pl. V, figs. 15, 16, and Pl. VI, figs. 1 to 4.

*Pleuromya inconstans* Cragin, 1897, Jour. Geol., vol. 5, p. 817, footnote, and p. 819.

Though outnumbered at many points by its associates, this is the most generally distributed fossil of the Malone formation. It ranges through the entire Theta subdivision of the Malone hills (Trio) section, or so much of it as is exposed at the locality 1½ miles east of Malone station, whence several hundred specimens were obtained. It was also collected by me in the lower part of limestones overlying conglomerate in the anticline at the eastern base of Malone Mountain, about 1 mile from the southern end, and was, I believe, found in poorly preserved examples in the gap west of the Trio, with *Trigonia*

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*ryschetzkii* and *Astarte malonensis*. The material collected by Doctor Stanton includes part of that from the first two of these and also specimens from the following localities: Two miles west and also about the same distance south of west of Malone station (here in Nos. 13 and 25 of his Malone Mountain section); foothill west of Malone Mountain, 2 miles north of its southern end; and west base of the mountain, near its southern end.

On the anterior part of the umbonal region of this shell there descends to the base a zone of constriction, as if the shell, when plastic, had been pinched, making the valves there gently concave and the base a little reëntrant, a feature which is often pronounced, though sometimes scarcely perceptible. When viewed from below, the base is usually seen to be twisted, presenting a more or less decided right-and-left sigmoid flexure. The right hinge margin overlaps the left. The shell gapes narrowly at the posterior end.

This fossil well sustains the reputation of the Pleuromyas for variability, meriting its specific name even better, if possible, in Texas than in Mexico. Manifold shades of form present themselves—some natural, others dynamical modifications of these—but all seem to intergraduate, and the specific place of many of them becomes indeterminable the moment an attempt is made to group them in more than one species. For this reason and because some of the specimens agree perfectly with those described and figured by Castillo and Aguilera from the Upper Jurassic of San Luis Potosi as *Pleuromya inconstans*, all are referred to that species.

The cuneate, the subcylindrical, and the Gresslya-like variations that have been recorded from the Sierra de Catorce, all are represented in the collections from the Malone district also. What appears to be the central phase for the latter district may be described as follows: The posterior terminal region of the shell is usually somewhat narrowed, sometimes strongly so, and is recurved or obliquely upturned; the anterior margin descends in a convex oblique line to an obtusely pointed or narrowly rounded corner in which it meets the horizontal or often somewhat downward-deflected anterior prolongation of the base. The anterior end thus presents a "Roman-nosed," or "hook-nosed," appearance, and the shell as a whole, viewed laterally, presents a sigmoid flexure, while the basal margin presents such flexure whether viewed from the side or from below. This is by far the most abundantly represented form of the species in the Malone district, and it attains the largest size. That it also occurs in the Sierra de Catorce is indicated by Castillo and Aguilera's very excellent and comprehensive description of the species, of which a translation is here added:

Shell inequilateral, of variable form, sometimes truncate on the anterior border, sometimes with this same border salient; the general dominant form is ovate

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trigonal. Buccal region little developed, extremely small compared with the anal region; excavated below the beaks, with its extremity rounded in some individuals, in others obliquely truncated, and salient in its lower part, which is continuous with the ventral border forming an obtuse angle. Beaks situated in the anterior third of the shell, varying their position in the different individuals from nearly terminal to subcentral; broad, convex, sometimes presenting two obtuse keels, one on each side of the apex of the beak. Anal region very large, convex, or depressed, narrowed toward its extremity, which is rounded. Dorsal border straight or slightly concave on the anal side, considerably excavated on the buccal side. Ventral border nearly straight, feebly raised at the extremities, but notably more at the anal side. Flanks sometimes very convex, giving to the shell a cylindrical form, and sometimes depressed so that they make it cuneiform; the greater convexity is always in the anterior part of the shell and below the beaks. Surface ornamented with concentric furrows which contrast with the fine lines of growth. Length, 34 to 63 mm.; breadth with relation to the length, 0.47 to 0.64; thickness with relation to the length, 0.31 to 0.43.

Castillo and Aguilera supplement this description with the following remarks:

We possess of this species only molds and imperfect examples, but these show the ornamentation of the shell and its very feeble thickness. The variation in the characters of this species is not limited merely to the contour and the other details of form of the shell, but is also manifested in the mode of occurrence of the shell, which is equivalve in the more convex forms and evidently becomes more and more inequivalve in so far as it reaches forms in which the right valve is more elevated than the left in such a manner that the dorsal border before and behind the beaks passes over the dorsal border of the opposite valve, exactly as in the Gresslyas, to which genus these forms could be referred without hesitation if they were found isolated, as to some extent the umbonal crests of which we have spoken above would make this position of the shell in the genus Gresslya more proper, since the obtuse furrow which is found along the umbonal crests somewhat resembles the oblique furrow which the molds of the Gresslyas present in the right valve and which in these corresponds to the internal lamina. Fortunately we have met with abundant examples which have permitted us to follow all the variations of the shell, forming a series whose extremes, taken without the intermediate forms, could without hesitation be referred to the genera Pleuromya and Gresslya, respectively.

### PLEUROMYA INCONSTANS var. CURTA var. n.

Pl. XVIII, fig. 4; Pl. XIX, figs. 1, 2.

Cuneate-oblong to cuneate-ovate, much shorter than the lengths of *Pleuromya inconstans* that prevail in the Theta member of the Malone formation, and rather compressed; the narrowly gaping posterior region of the shell slightly recurved, obliquely truncate; anterior region closed; ventral margin gently and evenly convex: dorsal margin much less excavated before the beaks than that of *Pleuromya peregrina* d'Orbigny; beaks more nearly terminal than in that species, often unequally elevated, the right being the higher, as seen in some

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species of Pleuromya and more commonly in Gresslya, the casts, however, lacking the pronounced right dorsal groove of the latter genus.

*Occurrence.*—In the horizon of *Exogyra potosina*, *Gervillia cinderella*, etc., at the west base of the southern part of Malone Mountain, and in the Theta member of the Malone Hills, 1½ miles east of Malone station. The types are from the former locality. At both places the type variety of *Pleuromya inconstans* as figured by Castillo and Aguilera also occurs, but in the former situation *curta* is common, while in the latter it is rare.

This form, so far as is indicated by the known material from the Malone Mountain locality, does not intergraduate with *Pleuromya inconstans*, and may represent a distinct species; but at the locality in the Malone Hills some of the forms of the multivariant *inconstans* seem to lead up to it, and it is therefore here considered a variety of that species. Its general proportions are not unlike those of the Callovian species *Pleuromya peregrina* d'Orb., from which it is distinguished by the recurved posterior region, the position of the beaks, and the less decidedly excavated anterior dorsal margin.

A Gresslya-like specimen of Pleuromya from the locality east of Malone station, whose form resembles somewhat that of *G. gregaria* Goldfuss, is provisionally considered as a mechanical deformation of this variety, though it may be such of one of the shorter examples of the variety *inconstans*, or even be specifically distinct.

## ANATINIDÆ.

### Genus ANATINA Lamarck.

#### ANATINA OBLIQUIPLICATA sp. n.

Pl. XVI, figs. 7, 8.

Shell among the smaller species of its genus, relatively compressed, inequilaterally elongate-oblong, rounded anteriorly, attenuated back of the beaks; the gaping posterior side shorter than the large and closed anterior; the shell somewhat pinched or concave on the ventral part in advance of the beaks (the ventral margin a little tortuous?); beaks small, low, situated near the limit of the anterior third; surface of the thin valves ornamented with concentric growth lines, and on the anterior region with a series of coarse and prominent, oblique undulatory folds which are nearly straight and trend about equally upward and forward. The folds are obtuse at summit and are separated by subequivalent round-bottomed intervals; the distal 5 occupy the valve to a distance of about 14 mm. from its antero-ventral margin.

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*Measurements.*—Height, 23 mm.; length, 53 mm.; breadth, 14 mm. Beaks placed at 30 mm. from the anterior extremity.

*Occurrence.*—Eight specimens from locality 1½ miles east of Malone station.

### ANATINA? PLICULIFERA sp. n.

Pl. XVI, figs. 9, 10.

Shell of small medium size in the genus, oblong, anteriorly rounded, posteriorly truncate, strongly compressed, moderately gaping at anterior and posterior extremities; the posterior region relatively little contracted; beaks low, narrowly compressed with the shell itself, situated about at the posterior limit of the anterior third of the shell; surface ornamented with strong, subequal, concentric plicules and grooves.

*Measurements.*—Height, 29 mm.: length, 49 mm.; breadth, 14 mm.

*Occurrence.*—A mile and a half east of Malone station. Represented by only one specimen.

There is some appearance of an anterior radial angulation of the shell, directed forward and downward to the anterior extremity; but the condition of preservation of the type is such as makes it impossible to determine whether this is really a feature of the shell or not.

## Genus THRACIA Leach.

### THRACIA? MALONIANA sp. n.

Pl. XIX, fig. 6.

Shell very thin, inequilateral, compressed, commonly about the size of *Thracia incerta* Agassiz,[a] sometimes larger, inclined to be more posteriorly produced, or heel-like, at the lower anterior border, trapezoid-ovate; posterior side narrowly gaping in the upper part; beaks of moderate size and elevation, situated about as in the *T. incerta*, their posterior slope angulated; surface marked with parallel, moderately elevated, compressed linear, or cariniform, concentric plicules separated by partly equal and partly unequal intervals of two or three times their own width.

*Measurements.*—Of considerably the largest example, height, 42 mm.; length, about 60 mm.; breadth, about 20 mm. Of a more common size, height, 37 mm.; length, 49 mm.; breadth, 18 mm.

*Occurrence.*—Six specimens, all casts, two of which show characteristic traces of the markings, were collected 1½ miles east of Malone station.

[a] As figured in Zittel's Handbuch, vol. 3, fig. 186.

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## MYIDÆ.

### Genus CORBULA Bruguière.

#### CORBULA ? MALONIANA sp. n.

Pl. XIX, fig. 7.

This name is provisionally proposed for a small, transverse, tri angular-ovate, moderately ventricose cast of a right valve belonging apparently to this genus, but unknown as to hinge or shell, obtained by Doctor Stanton from the same horizon that yielded the broadly triangular examples of *Exogyra potosina*, at the west base of Malone Mountain, a short distance north of its southern end. The height is about six-tenths of the length; the posterior end is slightly produced or pointed; the beak is pyramidal; the pallial line is coarse and strongly impressed. The species should possibly be referred to Neæra.

*Measurements.*—Height, 5 mm.; length, a little more than 8 mm.; breadth indicated for cast (that of the left valve being restored), about 4 mm.

## PHOLADIDÆ.

### Genus MARTESIA Leach.

#### MARTESIA MALONIANA sp. n.

Pl. XIX, figs. 3–5.

The types of this species are two casts of compressed-conoidal shape, with portions of the shell, in matrix. They are straight (not at all arcuate) and taper rapidly from the large anterior region. The compression is scarcely expressed in the umbonal region, but increases posteriorly. The base is rectilinear. Radiating downward from either beak to the base are two remote, transversely striated furrows, of which the anterior is the wider and the posterior is the more deeply impressed.

The markings seen on the casts are apparently an index of those peculiar to the shell. The casts do not indicate the character of the accessory plates.

*Measurements.*—The casts measure, height, 11 mm.; breadth, 10 to nearly 11 mm.; length, upward of 15 mm.; the posterior extremity of each being broken off.

*Occurrence.*—Obtained by Doctor Stanton in No. 13 of his Malone Mountain section, on the west side of Malone Mountain, south of west from Malone station. Besides the types, a considerable number of less satisfactorily preserved casts and fragments of casts were collected in their borings in fossil wood, at the same locality.

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A cast of Martesia referred to this species, obtained at the anticline in the east side of Malone Mountain about 1 mile north of its southern end, shows a more posteriorly produced form than might be inferred from the above-described types, indicating that a considerable length has been broken off from each of the latter.

Borings presumed to have been those of Martesia were also found 1½ miles east of Malone station.

## GASTROPODA.

### PLEUROTOMARIIDÆ.

### Genus PLEUROTOMARIA Defrance.

PLEUROTOMARIA CIRCUMTRUNCA sp. n.

Pl. XIX, figs. 8, 9.

Shell conical, consisting of 5 to 6 flattened or in part concave whorls, the slope of spire nearly straight, that of the entire shell, however, concave, owing to the form of the body whorl; spire acute; sutures lightly impressed, bordered by a low elevation above and below; body whorl concave above the peripheral zone, its periphery canaliculate-truncate, or having two low, abrupt angulations with a narrow, shallow-concave belt between them (and which, in the poorly preserved and sometimes more or less distorted specimens commonly found at the type locality, occasionally appears like a merely flat truncation); surface of the entire shell ornamented with fine, crowded, revolving raised lines, so minute as to be scarcely visible to the naked eye, and of which (in one of the types) there are 11 on the peripheral canal of the body whorl. The aspect of the peripheral canalicular truncation is outward and slightly downward.

*Measurements.*—Height, 20 mm.; breadth, 19 mm.; angular divergence of the slopes (excluding the body whorl), 66°.

*Occurrence.*—One and a half miles east of Malone station, in the lower part of the Theta subdivision of the section there exposed; with *Delphinula stantoni*, *Turbo? beneclathratus*, *Natica williamsi*, *Nerita nodilirata*, *Gervillia corrugata*, etc. Represented by eleven examples.

### TROCHIDÆ.

### Genus TURBO Linnæus.

TURBO ? BENECLATHRATUS sp. n.

Pl. XIX, figs. 10, 11.

Shell rather small, turbinate-conical, composed of about 4 ventricose whorls; spire and body whorl about equal in height; body whorl

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flattened and angulated on its upper part, the flattened zone being rather narrow and adjacent to the suture; aperture subovate; outer lip thin (?); inner lip covered with a calcareous callus, which is so arched as to indicate the presence of a low fold or tooth-like protuberance below; entire surface ornamented with a regular, open latticework of narrow, strongly elevated, transverse ribs, which are crossed by similar but somewhat more delicate revolving ones, the points of intersection being slightly protuberant to subtubercular, and the rectangular included intervals being gently concave and each marked by several raised growth lines.

*Measurements.*—Height, 19.5 mm.; breadth, 17 mm.

*Occurrence.*—A mile and a half east of Malone station; with *Gryphæa mexicana*, *Pleurotomaria circumtrunca*, *Natica williamsi*, etc. Known only by a single specimen, which has the base and the margin of the outer lip broken off. It is possible that specimens with the apertural characters well preserved might show this shell to belong to Purpurina.

## Genus DELPHINULA Lamarck.

### DELPHINULA STANTONI sp. n.

Pl. XIX, figs. 12–14.

Shell rather small, conoidal-turbinate, narrowly umbilicate, consisting of 4½ ventricose whorls, thick, especially in the vicinity of the peristome; spire about equal to the body whorl in height; aperture circular or nearly so; whorls rather closely ornamented with revolving lines of crowded and small but prominent granules, each granule shown, when the ornamentation is well preserved, to consist of a stout hood-like imbrication; body whorl flattened above in a rather broad zone that looks upward and outward, and is externally limited by an angulation that is marked by a line of relatively coarse and prominent hood-like imbrications, below which, in a narrow zone, the surface of the whorl is again somewhat flattened and looks outwardly, a second line of relatively coarse and prominent granules traversing the flattened upper slope of the body whorl, just below the suture. Between the upper and lower lines of coarse imbrications there are two lines of the smaller ones, and between the lower and the umbilical border there are nine.

*Measurements.*—Height, 16 mm.; breadth, 13 or 14 mm.; angular divergence of slopes, 80°.

*Occurrence.*—A mile and a half east of Malone station, in the lower exposed part of the Theta; associated with *Natica williamsi*, *Pleurotomaria circumtrunca*, *Gervillia corrugata*, *Gryphæa mexicana*, and many other, especially of the smaller of the Malone fossils. Five

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specimens were collected, four of them by Doctor Stanton, after whom the species is named.

## NERITIDÆ.

### Genus NERITA Linnæus.

#### NERITA NODILIRATA sp. n.

Pl. XX, figs. 1–4.

Shell thick, composed of 2½ to 3 whorls, its very obtuse-apexed interior cast loosely coiled and making only about a revolution and a half; body whorl obtusely angulated above the middle, somewhat concave above the angulation and again convex above the concave zone; spire very small, rising but little above the body whorl; aperture semilunar; peristome considerably thickened below; columellar area broadly flattened and overspread with a callus; whorls transversely trenchant-striate, or marked with close and abruptly elevated transverse lines, and bearing tubercular or noded ribs; exposed parts of the spire whorls and the corresponding (upper) part of the body whorl bearing rather remote, compressed, transverse ribs, each of which bears 2 remote nodes (the lower node being at the locu. of angulation in the body whorl and just above the inferior suture in spire whorls), these ribs continued as simple ridges across the lower part of the whorls in very young shells, but on the body whorl of older ones giving place to 4 or 5 revolving interrupted ribs or rows of low, elongate granules or tubercles.

*Measurements.*—Height, 27 mm.; breadth, 30 mm.; these dimensions representing considerably less than the maximum size. The two largest specimens at hand, though too imperfect for exact measurement, indicate dimensions between one-third and one-half greater.

*Occurrence.*—Especially abundant, with *Natica williamsi* and other Gasteropoda, in lower strata of the exposed part of the Theta, between the Trio and the Truncate mound, being represented in my collection by 54 specimens.

The species belongs to the subgenus Lissochilus.

#### NERITA FINLAYENSIS sp. n.

Pl. XIX, fig. 15.

General form somewhat like that of *N. nodilirata*, both body whorl and spire, however, a little more elevated; whorls few; body whorl with an even, obtuse, revolving angulation near the middle, the same being obsolete near the aperture, where the shell is almost evenly

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rounded, and gradually becoming noticeable as it recedes from it at half a turn from the aperture; the same angulation apparently continued on the lower part of the spire whorls; base of first spire whorl rising abruptly from the upper margin of the body whorl, the suture thus being strongly indicated; surface of shell devoid of transverse (vertical) ribs or nodes, plain, crossed with finer and coarser growth lines.

*Measurements.*—Height, about 20 mm.; breadth, 18.5 mm.

*Occurrence.*—One specimen, obtained in foothills at the northwest end of Malone Mountain, about 2 miles east-southeast from Finlay station.

### NERITA PEROBLATA sp. n.

Pl. XIX, figs. 16, 17.

Shell obliquely-depressed oval, consisting of 2 whorls; spire involved, or rising but feebly above the adjoining whorl border; body whorl rapidly increasing its centrifugal expansion with spiral distance from its origin, convex on its outer and lower parts, flattish on an upper zone which is limited below by an obsolescent spiral ridge; aperture semicircular; inner lip without teeth, bearing a thick, flat-surfaced callus; outer lip with simple acute border; surface of shell plain, presenting, besides the obsolescent spiral ridge, only growth lines, some of which, more pronounced than the others and occurring at irregular intervals, constitute coarse constrictions and ridges which are conspicuous also on parts of the cast from which the shell has been removed. Of the outer lip in the type only the lower border is preserved, but this shows the simple and acute character above described.

*Measurements.*—Height, 41 mm. (of which the spire occupies barely 2); breadth, 44 mm.; height of aperture, 35 mm.; greatest (obliquely centrifugal) diameter of same, 29 mm.

*Occurrence.*—Known only by one example, which was associated with *Nerita nodilirata*, etc., 1½ miles east of Malone station.

Max Schlosser[a] comments on the Jurassic forms of this genus as follows, translated:

> The Jurassic Neritas are distinguished from the typical by the imperfect (*Nerita chromatica* Zitt.) or wholly obsolete toothing of the inner lip (*Nerita zitteli, neumayri*). The outer lip is always simple with cutting border. As the only departure from this, one observes a greater or less thickening. On the inner lip appears a mostly very strong, often indeed high-arched callus. The general habit, however, agrees so well with the recent forms that the erection of a new subgenus appears inadvisable.

[a] Die Fauna der Kelheimer Diceras-Kalkes: Palaeontographica, vol. 28, p. 93.

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## TURRITELLIDÆ.

### Genus TURRITELLA Lamarck.

#### TURRITELLA BURKARTI sp. n.

Pl. XX, fig. 5.

Shell turreted, of moderate size for a Turritella, consisting of numerous whorls, which are greatly convex, wider than high, and medially carinate by virtue of the ornamentation, bearing four granulated, revolving raised lines, of which one, much larger and more prominent than the others, and more decidedly cariniform, crosses the middle of the whorl, while 2 of the 3 smaller and subequal ones are placed, respectively, just below and just above the upper and lower limiting suture, the remaining one being placed between the uppermost one and the large carina, and nearer to the former than to the latter, so that the 3 intervals increase serially from uppermost to the lowermost. Aperture unknown.

*Measurements.*—The type and only known specimen includes four largely embedded whorls within a span of 14 mm. The largest one of these whorls has a height of 4.5 mm. and an exposed breadth of 5.5 mm., which is less than the true breadth, only about a third of each whorl being free from the matrix.

*Occurrence.*—In the anticline on the east slope of Malone Mountain, nearly 1 mile north of its southern end; collected by Doctor Stanton.

The species is named after a former traveler in Mexico, Mr. Joseph Burkart, who, as quoted from his "Aufenhalt und Reisen in Mexico in den Jahren 1825 bis 1834" by Castillo and Aguilera, on page V of their Fauna Fosil, has recorded a Turritella (identified as to genus by Professor Goldfuss) as collected by him in the Mineral de Catorce some three-quarters of a century ago. The species collected by him may, by no means improbably, have corresponded in geological age and in kind with the Malone species above briefly described.

## VERMETIDÆ.

#### VERMETUS CORNEJOI Castillo and Aguilera ?.

Pl. XX, fig. 6.

*Vermetus* (*Burtinella*) *cornejoi* Castillo and Aguilera, 1895, Bol. Com. Geol. Mex., No. 1, p. 12, Pl. VI, figs. 5, 6, and 7.

Eight specimens of Vermetus, from the Theta, 1½ miles east of Malone station, are referred to this species. They show only the inner

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whorls and only one of them approaches in size the smallest one of the types figured from the Sierra de Catorce by Castillo and Aguilera. The cavity is oval in cross section, and its lesser diameter is equal to about four times the thickness of its wall.

The following is a translation of the specific diagnosis:

Shell small, free in the adult state, tubular, inrolled planorbiform, sinistral, last whorl unrolled. Tube rugose, bearing two spiral carinæ at the base, the exterior more prominent than the interior, inclosing between them a narrow furrow. Aperture circular or slightly oval. Surface furnished with sinuous growth lines and quite pronounced on the upper part of the whorls, less so on the inferior part.

## NATICIDÆ.

### Genus NATICA (Adanson) Lamarck.

#### NATICA WILLIAMSI sp. n.

Pl. XX, figs. 7, 8.

Shell of medium size in its genus, imperforate; whorls 5; spire small, short, and concave, giving it an apiculate aspect when well preserved, its height about one-fifth of that of the entire shell; body whorl large, obliquely inverted pyriform, flattish on the region below the weakly impressed suture, the greatest convexity being somewhat above the middle of the whorl; inner lip and columellar region covered with a layer of callus; aperture rather long and narrow, narrowing gradually upward, rounded below, subacute above.

*Measurements.*—Height, 40 mm.; breadth, about 30 mm. Other specimens, not allowing precise measurement, indicate about one and a half times these dimensions.

*Occurrence.*—A mile and a half east of Malone station, associated with *Natica inflecta*, *Nerita nodilirata*, etc. At this locality it is one of the commonest of the Malone Gastropoda. Nearly a hundred specimens are in hand, most of them poorly preserved owing to weathering.

This shell is named for Mr. John W. Williams, who in 1897 was prospecting in the Quitman Mountains not far from Malone, and whose exceedingly kind and thoughtful interest in my work, displayed in many practical ways, contributed not a little in that year to the pleasure as well as the success of my explorations in the Malone district.

In its low and concave spire and feebly impressed suture, and a tendency to greater breadth in the upper part of the body whorl, the shell recalls Actæonella and constitutes an unusual phase of Jurassic Amauropsis.

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### NATICA INFLECTA sp. n.

Pl. XX, figs. 11, 12.

Shell of medium or rather small size in its genus, smaller than *Natica williamsi*, consisting of about 5 whorls, imperforate, of rather stout or medium elevated habit; the spire not concave, much more elevated than that of the above-mentioned species, its height being about two-fifths of that of the shell, composed of convex, well-rounded whorls, separated by sutures which are deeply and rather suddenly impressed, a narrow upper border of the whorls being gently and subhorizontally flattened; aperture narrow, or elevated, considerably less so, however, than that of *N. williamsi*, narrowly rounded below, obtusely pointed above; columella slightly produced, inner lip and spindle callus-plated; surface smooth or crossed only with ordinary growth lines.

*Measurements.*—Height, 35 mm.; breadth, 27 mm.; height of spire, 14 mm. A second example has dimensions about 75 per cent greater.

*Occurrence.*—A mile and a half east of Malone station; with *Natica williamsi*, from which the species is readily distinguished. The writer obtained only three shells of *N. inflecta*, one of which, a young example, has the body whorl crossed with alternating dark and light bands, parallel with the growth lines. An example was obtained by Doctor Stanton at the same locality, and one by him in foothills at the northwest end of Malone Mountain, about 2 miles east-southeast from Finlay station.

The species seems to stand close to the English Oxfordian form, *N. arguta* Phil., and is referred to the subgenus Amauropsis, to which all of the Naticæ now known from the Malone formation seem to belong.

### NATICA FINLAYENSIS sp. n.

Pl. XX, figs. 15, 16.

Shell of medium size in its genus, subovate, imperforate; whorls about 5, moderately convex, those of the spire broad and low; body whorl large, elevated, oblique; spire more than a third and considerably less than half of the height of the shell, higher than the spire of *Natica williamsi*, lower than that of *N. inflecta;* suture much more strongly impressed than that of the former and much less so than that of the latter species; aperture elevated, arcuate-pyriform, pointed above, rounded below; inner lip not free-margined, and apparently with little callus, concave below, convex above; surface plain.

*Measurements.*—Height (approximately), 42 mm.; breadth, 30 mm.

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*Occurrence.*—The type and only known example was obtained by Doctor Stanton in foothills at the northwest end of Malone Mountain, a little over 2 miles east-southeast from Finlay station.

NATICA BILABIATA sp. n.

Pl. XX, figs. 9, 10.

Shell rather small, consisting (apparently) of about 3½ strongly convex whorls; without umbilicus; provided with a narrow, elongate, and shallow cleft formed by the eversion of the inner lip; spire short, its height much less than that of the aperture; suture well impressed; aperture obliquely ovate, about two-thirds as high as the entire shell; outer lip simple; inner lip everted, thickened below, its border quite free in the middle region, where it pursues a nearly straight course and constitutes the outer bound of the small umbilical cleft; exterior smooth except for the numerous ordinary growth lines.

*Measurements.*—Height, about 21 mm.; breadth 18 mm.

*Occurrence.*—One specimen, from the same fragment of limestone that bore one of the types of *Unicardium semirotundum;* 1½ miles east of Malone station. Collected by Doctor Stanton.

## PYRAMIDELLIDÆ.

### Genus PSEUDOMELANIA Pictet.

PSEUDOMELANIA GOODELLII sp. n.

Pl. XXI, fig. 10.

Shell large, turreted, consisting of numerous smooth, flattened, upwardly-imbricated whorls, of which the lower spire whorls are nearly twice as wide as high; shell substance thick, sometimes showing, parallel with the height (length) of the shell, numerous rather narrow, unequal, or subequal, alternating dark and light bands, of which there are perhaps as many as 50 of either shade on each whorl.

*Measurements.*—Breadth of body whorl in largest specimen, 50 mm.; breadth of first spire whorl, 43 mm.; height of same, 21 mm. The shell in this specimen apparently had a height of 170 to 180 mm. In a second example, with body whorl 44 mm. in breadth, the shell height is about 165 mm.

*Occurrence.*—This, the largest of the Gastropoda known from the Malone formation, is only moderately common; and all of the material of it obtained is more or less fragmentary, though collectively affording a fair knowledge of the species. The above description of it, based on all of the material now known, supersedes an earlier one in manuscript made by me at a time when my knowledge of the

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species was derived solely from an imperfect specimen, which was from the locality 1½ miles east of Malone station. Besides a fragment from the locality just named, Doctor Stanton's collections include material of this shell from the following localities: From No. 13 (the Nautilus horizon) of his Malone Mountain section, on the west side of the mountain, southwesterly from Malone station; and from about 1 mile east of Finlay station, one of the specimens from the last-named locality being in rock with *Trigonia calderoni*. A poorly preserved portion of probably this fossil was also found by Doctor Stanton in the anticline in the eastern slope of Malone Mountain nearly 1 mile north of its southern end.

The species is named after the late Mr. Robert W. Goodell.

## NERINEIDÆ.

### Genus NERINEA Defrance.

#### NERINEA GOODELLII sp. n.

Pl. XXI, figs. 1–3.

Shell turriculate to cylindrical-turriculate, not exceedingly attenuate; walls thin, the outer one bearing internally one prominent, thin, and acute fold which extends scarcely half way across the chamber; columella rather slender, in part hollow, bearing 2 thin folds both smaller than the outer fold; whorls apparently 17 or more, low, usually as much as one and a half times and sometimes about twice as wide as high, concave, the opposed borders of successive whorls tending to form a low cariniform ridge with linear suture on the summit line, the surface of each whorl ornamented with 3 or 4 linear, raised, revolving lines and ordinary oblique, somewhat sinuous growth lines. Of the three internal folds, the upper columellar one, which descends from the junction of the upper wall of the chamber with the columella, is the smallest and thinnest, yet is quite salient.

*Measurements.*—Breadth of largest whorls reaching 14 mm.; angular divergence of slopes 5° or 6° to 8°.

*Occurrence.*—Common in the limestone layers, and less so in the sandstone, at various levels in the Theta, 1½ miles east of Malone station; exceedingly abundant in some of the lower layers. Weathered-out specimens usually occur in segments of two or three to a dozen or more whorls. Besides the numerous specimens in my collection, which include some natural longitudinal sections, I have examined four specimens, one of which is an artificial section, submitted by Doctor Stanton. Several poor weathered sections were obtained near the south end of Malone Mountain, from a locality which yielded also a specimen of *Trigonia munita*,

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I have not been able to ascertain the maximum height of this shell, nor with certainty the number of whorls; but in 1 specimen only 4 mm. in breadth and about 17 mm. in height there are 15 whorls preserved, while probably 2 or 3 minute ones have been dissolved away at the summit.

The revolving lines of ornamentation on this shell are very delicate and commonly are not seen at all on weathered specimens.

In its internal ridges, as well as in the form of its whorls, the species resembles the Corallian form, *N. goodhallii* Sowerby.[a] It is named for the Messrs R. R. and R. W. Goodell, in recognition of their joint exploration of the Malone, an account of which has been given elsewhere.

For comparison with *Nerinea goodellii*, Doctor Stanton has handed the writer some fragments and fragmental prepared sections of a Nerinea "broken from the hand specimen that bears the larger of the types of *Trigonia taffii* Cragin."[b] These resemble *N. goodellii* superficially, but appear to lack revolving lines and to present sectional details which seem to refer them to a different species, although the unsatisfactory state of their preservation forbids full assurance that their internal characters are all correctly understood. In the Nerinea from Bluff Mesa the fold on the outer wall is relatively thicker and more obtuse and is altogether larger than in *N. goodellii*, extending a little more than half way across the chamber; the lower columellar fold is also coarser than that of *N. goodellii*. The upper columellar fold is not very clearly indicated; if present at all it is apparently obsolescent, or at least much smaller than that of *N. goodellii*.

### NERINEA CIRCUMVOLUTA sp. n.

Pl. XXI, figs. 4, 5.

Shell cylindrical-turriculate; walls thin, with one outer and two columellar folds situated as in the much more common *Nerinea goodellii*, all of the folds delicate, the outer one less so than the other two; columella solid, rather slender; whorls flat or only very slightly concave, one and a fourth times as high as wide, apparently at least as numerous as in *N. goodellii*, presenting an imbricated appearance at the suture, as if the outer wall of each whorl slightly overlapped

[a] Described and figured in exterior and in section by James de Carle Sowerby, in Dr. William Henry Fitton's "Observations on some of the strata between the Chalk and the Oxford Oölite in the southeast of England;" Trans. Geol. Soc. London, 2d ser., vol. 4, 1836. Sowerby's figures (12 of Pl. XXIII, loc. cit.) represent it as several times larger than the shell here described as *goodellii*. The figures 1294 of the fourth edition of Dana's Manual are partial and much reduced copies of Sowerby's figures, but, unlike the latter, represent the shell as thick-walled.

[b] The large valve from Bluff Mesa, which is the real type of this Trigonia. See remarks on *Trigonia taffii* on page 10.



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the whorl next above; suture subtended by a narrow, plain band, which is itself limited below by a delicate striæform groove; surface ornamented only with growth lines, which are for the most part vertical, becoming strongly recurved as they near the upper border of the whorl.

*Measurements.*—A fragment 6.5 mm. wide at the lower end has 5 whorls in a height of 29 mm.

*Occurrence.*—The species is based on several segments collected and a longitudinal section prepared by Doctor Stanton, and which are from the locality 1½ miles east of Malone station.

## Genus NERINELLA Sharpe.

### NERINELLA STANTONI sp. n.

Pl. XXI, figs. 6–9.

In 1898 Doctor Stanton very kindly communicated a specimen of Nerinella, partly cut in longitudinal section, which he had obtained while collecting with me during the previous year from the same beds, 1½ miles east of Malone station, that yielded *Nerinea goodellii.*

It is exceedingly attenuated and, within 53 mm., includes 20 concave whorls from a number that must obviously have been much greater in the complete shell. The chamber has no columellar fold, but its outer wall presents a simple, short, and rather obtuse fold at about mid height. The whorls are crossed by numerous delicate growth lines and are ornamented with 4 equidistant, spiral, cariniform lines on the main part, besides 2 which are so close to the whorl borders as often to be difficultly distinguishable.

I find in my own collection, made 1½ miles east of Malone, a few incomplete and more or less weathered specimens of this fossil. One of these supplements Doctor Stanton's specimen as to the upper part of the spire, showing 16 additional whorls, with apparently a very few still to be added at the apex. Another represents a basal portion considerably broader than the larger end of Doctor Stanton's specimen, so that the number of whorls in this shell can be little, if at all, short of 50. The greatest breadth shown by any of these specimens is between 5 and 6 mm. The height of the shell is roughly estimated at about 100 mm.

This fossil is also recognized in material obtained by Doctor Stanton at the following places: In No. 13 of his Malone Mountain section, about 2 miles southwest of Malone station, on the west of the mountain; in about the same horizon something over 1 mile east of Finlay station, and in the anticline at the east base of the mountain, about a mile from its southern end.

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## CERITHIIDÆ.

### Genus CERITHIUM Adanson.

#### CERITHIUM ARCUIFERUM sp. n.

Pl. XX, fig. 13.

Shell small, turriculate, many whorled; spindle solid; mouth subquadrate; surface of the gently convex whorls ornamented with numerous fine revolving lines and with coarse transverse folds, or ribs, the latter strongly arched backward, the summit and more prominent portion of the arch being on the lower and more prominent portion of the whorls. Of the revolving lines there are about 17 on the first spire whorl, and of the arcuate folds there are about the same number on the body whorl.

*Measurements.*—Breadth, 7 mm.; angular divergence of slopes on the lower part of the shell, 21° or 22°.

*Occurrence.*—A mile and a half east of Malone station; with *Nerita nodilirata*, *Pleurotomaria circumtrunca*, etc. Only a single specimen lacking the lower end of the spindle and the upper part of the spire has been found.

Owing to the incompleteness of the lower extremity of the shell in the type the basal canal is not shown, but its presence in the complete shell and a reference to the genus *Cerithium* are indicated by the character of the spindle and the general habit of the shell, the latter being apparently that of the subgenus *Cerithinella*.

## ACTÆONIDÆ.

### Genus ACTÆONINA d'Orbigny.

#### ACTÆONINA ? MALONIANA sp. n.

Pl. XX, fig. 14.

Whorls 4 or 5; body whorl large, about three-fourths as wide as high in the cast, its sides gently convex; spire small, evidently not much exceeding one-fifth of the body whorl in height; aperture high and narrow, somewhat broadened below, and the inner lip apparently without fold; general surface as indicated by a preserved basal fragment, marked with delicate revolving grooves or striæ, the striæ separated by intervals wider than themselves.

*Measurements.*—Height (approximately), 14.5 mm.; breadth, 10 mm.

*Occurrence.*—Known only by a cast bearing two fragments of the shell; obtained by Doctor Stanton 1½ miles east of Malone station.

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When viewed from above, the cast presents a somewhat squared form, due apparently to the accident of rock pressure.

## CEPHALOPODA.

## NAUTILOIDEA.

### Genus NAUTILUS Breyn.

#### NAUTILUS BURKARTI C. and A. ?

Pl. XXII, fig. 1.

*Nautilus burkarti* Castillo and Aguilera, 1895, Bol. Com. Geol. Mex., No.1, p. 12, Pl. XXI, fig. 3.

I provisionally refer to this species an imperfect specimen of Nautilus of inflated form obtained by Doctor Stanton in No. 13 of his Malone Mountain section, on the west side of the mountain southwest of Malone station. The dimensions are much larger than those indicated by Castillo and Aguilera's figure and description of *N. burkarti*, which are perhaps those of a young example.

The Malone Mountain specimen gives the following measurements: Height of shell, 123 mm.; height of last whorl, 67 mm.; breadth of the latter, as restored, 86 mm. The height of the last whorl is therefore about 54.5 per cent and its breadth about 70 per cent of the height of the shell, as against 55 and 64, given as corresponding percentages for the type-specimen.

The following is a translation of the original description of the species:

Shell extremely inflated; spire composed of few whorls which cover more than three-fourths of the whorls preceding; flanks quite convex and attaining their greatest thickness near the umbilicus, whence they descend gradually toward the siphonal region, which is quite rounded; umbilicus narrow, deep, and funnel-shaped; aperture very much invaded by the spire whorl, wider than high, rounded on the upper part; surface nearly smooth, destitute of tubercles, bearing only marked growth lines, which make it slightly rough on some parts.

| | |
|---|---|
| Diameter | 49.00 mm. |
| Breadth of the last whorl in relation to the diameter | .55 |
| Thickness of the last whorl in relation to the diameter | .64 |
| Diameter of the umbilicus to the diameter | .23 |

#### NAUTILUS NAUFRAGUS sp. n.

Pl. XXIII, fig. 3, Pl. XXIV, fig. 3.

Shell involute, somewhat compressed; volutions deeply embracing, increasing rapidly in size, narrowed on the feebly convex flanks from

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a region of maximum, yet moderate inflation, near the umbilicus to the rather narrowly rounded periphery; septa about 24 to each turn, the sutures feebly waved or sigmoid; umbilicus narrow, filled with a shelly columella; surface of shell smooth. The position of the siphuncle has not been determined.

*Measurements.*—The greatest diameter of the larger specimen is about 122 mm. The height of the largest preserved part of the body-chamber in its median plane is about 50 mm. The height of the same part of the body-chamber over all, or measured on a tangent to the flank from the level of its umbilical border to the level of the periphery, is about 71 mm. (66 on one flank, 76 on the other flank, in the specimen as preserved, the umbilical axis having an oblique position, due to crushing). The original breadth of the same part of the body chamber, allowing for crushing, was apparently not less than 60 mm.

*Occurrence.*—Two imperfect specimens of this shell were collected by Doctor Stanton in foothills near the railroad, at the northwest end of Malone Mountain, about 2 miles east-southeast from Finlay station, the horizon not more than 200 feet above the gypsum bed.

## AMMONOIDEA.

### Genus OPPELIA Waagen.

#### OPPELIA ? FALLAX (C. and A.).

Pl. XXII, figs. 2, 3.

*Placenticeras fallax* Castillo and Aguilera, 1895, Bol. Com. Geol. Mex., No. 1, p. 17, Pl. VIII, figs. 1, 2.

This large, plain, compressed, and obtusely lenticular ammonite is rather common in the limestone portions of Theta subdivision of the Trio section, 1½ miles east of Malone station, but has been obtained thence in fragmentary specimens only.

The following is a translation of the original specific description:

Shell compressed, narrowly umbilicate. Spire composed of not very numerous embracing whorls, which almost completely hide the previous whorls. Flanks feebly convex, descending gradually toward the umbilical border and with the same regularity toward the siphonal region, which is rounded and a little more narrow than the flanks; the greatest thickness of the shell is on the umbilical border. Umbilicus very narrow and deep, with vertical walls, with uncarinated border. Aperture very high, considerably invaded by the spire whorl, rounded in the upper part, of nearly elliptical form. Surface of the shell smooth on the last whorls, bearing in the earlier whorls fine lines of growth. Diameter, 104 mm.; breadth of the last whorl in relation to the diameter, 0.54; thickness of the last whorl in relation to the diameter, 0.32; diameter of the umbilicus in relation to the diameter, 0.16.

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To the above description Castillo and Aguilera add the following remarks:

We place this species in the genus *Placenticeras*, notwithstanding that by its form it could be considered as a *Phylloceras*, by the characters of the sutural line which, though imperfectly visible in one of the specimens of our collection, does not present the saddles terminated by the roundels characteristic of the *Phylloceras*, only ramifications and subdivisions similar to those of the *Placenticeras*.

As it makes some departures from the characters belonging to most of its congeners, this ammonite may seem at first sight almost as much of an anomaly in the genus *Oppelia* as it was supposed to be in *Placenticeras*. But the suture, which has the lobes and saddles very few instead of many,[a] and has the first lateral lobe contrastingly the largest, sufficiently distinguishes it from the latter genus and relates it to *Oppelia* and *Haploceras*, with which also agree its involute, narrowly umbilicated shell, its rounded venter, its rather compressed lenticular form, and the absence of periodical constrictions. It seems indeed to have its closest affinities and to belong among the round-ventered, phylogerontic forms of *Oppelia* which occur in the latest Jurassic rocks, in which this genus makes its final appearance; the venter, in *O. fallax*, being rounded both on the outer and on the inner whorls.

The Malone *Oppelia* bears considerable resemblance to the Tithonian species, *O. waageni* Zittel, having about the same outward form and being of large size; but it apparently lacks a vestige of even such feebly expressed, coarse lateral ribs, or undulations, as are seen on that shell, and is more critically distinguished from it by the characters of the suture. The first lateral saddle is much narrower in the Malone ammonite than in *Oppelia waageni*, and the first lateral lobe—which is quite unsymmetrically branched in the latter shell—presents an almost symmetrical branching in *O. fallax*. In this last-mentioned character, *O. fallax* departs from the condition most common in *Oppelia* and approaches the usual condition in *Desmoceras*, from which genus it is separated by the absence of constrictions. The siphonal lobe is about half as long as the first lateral lobe and ends in two small branches on either side.

Though commonly represented from the Malone district by whorl fragments of dimensions not or little exceeding those given by Castillo and Aguilera for the examples from the Sierra de Catorce, the shell attains a much larger size. One specimen, of which considerable portions were collected 1½ miles east of Malone station, has in the largest preserved cross section of the body chamber, a height of about 145 and a breadth of at least 93 mm., while the diameter of

[a] My attention was first called to the few-lobed suture, as inconsistent with *Placenticeras*, by Doctor Stanton.

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the coil (a large part of whose periphery is preserved) must have considerably exceeded a foot. The specific identification is tentative, as it is based on the comparison of imperfect specimens with Castillo and Aguilera's description and figures. The specimen figured is a young individual and the only one in the collection that shows more than a fragment of a complete volution.

## Genus OLCOSTEPHANUS Neumayr.

### OLCOSTEPHANUS MALONIANUS sp. n.

Pl. XXIV, figs. 1, 2.

Shell large and moderately involute, consisting of massive whorls which are at least as high as or a little higher than wide, with flattish-convex flanks and broadly rounded periphery, about one-fourth of the height of each inner whorl embraced within the whorl next outer; umbilical costæ not at all resembling compressed tubercles, but heavy, long, and truly rib-like, traversing the lower and middle parts of the flank from the lower border to between half and two-thirds the height of the whorl, giving place at their upper ends to numerous compressed, narrowly round-topped costellæ which are fascicled mostly in threes at their origin, but are uniformly distributed upon the periphery of the whorls, over which they pass without interruption, swinging very little forward; suture strongly dissected, the two lateral lobes and saddles large and complexly branching, the external one especially so. The body chamber is unknown.

*Measurements.*—The largest known whorl section (which is in the septate portion of the shell) has the height and breadth about 110 and 105 mm.; an inner one about 58 and 57 mm., respectively.

*Occurrence.*—Only a few parts of whorls, most if not all of which belong to one specimen, were collected at the locality 1½ miles east of Malone station.

The species is intermediate in general proportions between the two species of *Olcostephanus* known from the Alamitos beds—which seem to correspond in some measure with the Malone formation—in Mexico: *O.* "af. *portlandicus* de Loriol" and *O. potosina* of Castillo and Aguilera.

## Genus PERISPHINCTES Waagen.

### PERISPHINCTES CLARKI sp. n.

Pl. XXIX, figs. 1, 2.

Shell large, discoidal, many whorled, broadly umbilicated; involution more than one-half; whorls ovate, the outer ones elevated or narrow-ovate in cross section, narrowed toward the venter, which is

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rather narrowly rounded; the flanks flattish-convex; umbilical border rounded; the wall of the outer whorl sloping rather gently to the next whorl within it, that of the inner whorls descending somewhat more steeply below; inner whorls ornamented with strongly elevated, moderately close, but not crowded, dichotomous ribs whose branches separate at about the middle of the flank and continuously cross the venter, the lateral ribs not noticeably enlarged on the umbilical border, this ornamentation becoming gradually changed to large low undulations on the outer whorls and almost vanishing before the (presumably plain or nearly plain) body chamber is reached; septal line with two strong lateral lobes, which are rather strongly dissected, and a deep suspensive lobe; the first lateral lobe large, twice or more than twice as long as the second, longer than the siphonal lobe, and having three strong terminal branches of which the outer is subtended by a smaller branch; the second lateral lobe pinnate, not distinctly branched at summit; a noticeable lobe, similar to the second lateral lobe, but slenderer and about two-thirds as long, stands between the first lateral and the siphonal lobe; suspensive lobe consisting of one tall pinnate lobe, with strongly trifid summit, which is outwardly preceded by a trio consisting of a small lobe flanked on either side by a lobule and is inwardly followed by two obtuse lobes the inner of which is very low and often 3-denticled. This description of the septal line relates to the later septa, the preceding ones being somewhat simpler.

*Measurements.*—Height of largest cross section of whorl preserved in the type, 85 mm.; breadth of same, 54 mm.; span of umbilicus opposite same section, 90 mm.

*Occurrence.*—The type represents a considerable and wholly septate part of the form and was obtained by Doctor Stanton from No. 13 of his Malone Mountain section on the west side of the mountain, about 2 miles southwesterly from Malone station. He obtained a fragment also on the east slope of the mountain near its southern end, about 200 or 300 feet above the heavy bed of gypsum which there forms the base of the mountain; and a poorly preserved specimen and fragment from foothills near the railroad, at the northwest end of Malone Mountain, a little over 2 miles east-southeast of Finlay station, not more than 200 feet above the gypsum bed of that locality.

It is not unlikely that this is the same species as that figured and briefly described from the Tithonian of Mexico as "*Perisphinctes sp.* (?)" by Castillo and Aguilera,[a] and compared by them in its ribbing with *P. lictor*, *P. haliarchus*, and *P. polygyratus*. The septal line bears considerable resemblance to that of the latter species, which, from the White Jura Beta, Quenstedt[b] figures under the name of "*Ammonites triplicatus albus.*"

[a] Fauna Fosil de la Sierra de Catorce, p. 35, Pl. XIX.
[b] Die Ammoniten des Schwäbischen Jura, pl. 100, fig. 8.

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The species is named for Dr. Wm. Bullock Clark, professor of geology in Johns Hopkins University and director of the Maryland geological survey.

### PERISPHINCTES AGUILERAI sp. n.

Pl. XXVIII, figs. 1, 2.

Shell large, discoidal; umbilicus large, spanning more than a third of the diameter of the shell, rather shallow, its wall descending almost vertically from a rounded border; whorls little involute, each concealing only between a fourth and a fifth of its predecessor, about three-fourths as broad as high, broadest in the lower third, their flanks flattened-convex, the venter rounded, apparently a little tectiform on the outer whorl; ornamented with very numerous compressed ribs, which arise independently at the umbilicus, have a somewhat backward inclination in ascending the umbilical wall, and cross the flanks with a gentle forward inclination and slight sigmoid flexure, bifurcating at about the mid flank into parallel branches that sweep strongly forward on the ventral region so that those of opposite sides meet on the periphery at nearly a right angle; the ribs, and especially the ventral ones, close, yet narrower than the round-bottomed intervals between them, the ventral ribs of the inner whorls being very fine, those of the outer whorls large, though still compressed and strongly elevated; septal line strongly dissected, apparently not differing from that of Perisphinctes, though hitherto observed only in part, the saddles at least not ending in roundels such as characterize the Phylloceratidæ.

*Measurements.*—Outer whorl attaining at least a height of 107 mm. and a breadth of 84 mm. The cross section of a smaller whorl has the same dimensions, 57 and 50 mm.

*Occurrence.*—Seven fragments of this species were obtained by Doctor Stanton from the foothills west of Malone Mountain, about 2 miles north of the southern end of the latter. The horizon is regarded by him as probably the same as one that yielded him specimens of the *Exogyra*, herein identified as *E. potosina* (narrow phase).

The species is named for Señor José G. Aguilera, director of the geological institute of Mexico.

### PERISPHINCTES POTOSINUS C. and A.

Pl. XXIII, fig. 1.

*Perisphinctes potosinus* Castillo and Aguilera, 1895, Bol. Com. Geol. Mex., No. 1, p. 31, Pl. XVII, fig. 1 and Pl. XXIV, fig. 2.

Among the specimens from the locality 1½ miles east of Malone station is a fragment of a Perisphinctes belonging to the series of

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*P. contiguus* Catullo, and that seems to agree sufficiently with the description and illustrations of *P. potosina* C. and A. The lateral ribs, in form, size, interspacing, and manner of trifurcation, are those of *P. contiguus*, from which the Malone sheil differs in the more anteriorly inclined lateral ribs and in having the ventral ribs distinctly curved forward as they approach the periphery, on which they are slightly extinguished. The last-named feature, however, is not a specific difference; for while the ventral ribs in *P. contiguus* are usually uninterrupted, a slight peripheral attenuation of them is noted by Toucas [a] as occurring in some varieties of this species in the Carpathians.

The fragment agrees in size with an intermediate part of the outer whorl of *P. contiguus* or *P. potosinus*, and the cross section of whorl which it indicates is about three-fourths as broad as high, measuring 24 mm. in height and 18 or 19 mm. in breadth.

Siemiradzki [b] refers to *P. potosinus* as apparently identical with *P. kokeni* Behrendsen,[c] but there seem to me to be considerable differences between the two species. These differences, if we accept the description and the figure of the adult (Pl. XVII, fig. 1) and exclude the smaller and doubtfully pertinent figure (Pl. XXIV, fig. 2) given by Castillo and Aguilera of their *Perisphinctes potosinus*, are as follows:

| *P. kokeni.* | *P. potosinus.* |
|---|---|
| Involution ⅓. | Involution ⅔ to ¾. |
| Whorls broader (thicker) than high. | Whorls higher than broad. |
| Whorl cross section quadrilaterally rounded. | Whorl cross section flat-sided ovate. |
| Venter flatly rounded. | Venter rounded. |
| Lateral ribs bifurcate. | Lateral ribs bifurcate, the larger number becoming trifurcate on the last whorl. |
| Simple part of lateral ribs rather slender. | Simple part of lateral ribs rather stout. |

### PERISPHINCTES FELIXI C. and A.

Pl. XXIII, fig. 2.

*Perisphinctes felixi* Castillo and Aguilera, 1895, Bol. Com. Geol. Mex., No. 1, p. 25, Pl. XVI, fig. 1.

A species of Perisphinctes apparently not distinct from *P. felixi* C. and A., but intermediate in some of its characters between the latter and the closely allied, if indeed really distinct *P. lauri* C. and A., is represented from the locality 1½ miles east of Malone station by a specimen showing part of three successive whorls.

The whorls are rounded in cross section, having their height and

[a] Bull. Soc. Geol. France, 3d ser., Vol. XVIII, p. 582.
[b] Monogr. Beschr. Perisphinctes, p. 170.
[c] Zeitschr. d. Deutsch. Geol. Gesellsch., Bd. 43, p. 406, pl. 24, figs. 1 and 2. 1891.

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breadth about equal (25 mm.), yet having their greatest breadth in the lower part. The involution is between ⅓ and ½. The ribs are heavy and inclined forward; mostly bifurcate at about the middle of the flank, but in one instance a rib is seemingly bidichotomous, the first bifurcation taking place on the umbilical border. The ventral ribs pass over the periphery without interruption, but are curved forward as they approach the median line so as to make a very obtuse angle, at which many of them suffer a very slight weakening. The specimen does not show the largest part of the last whorl, a fact to which the almost uniformly bifurcate character of the ribbing is probably due.

Doctor Stanton also has collected at this locality a small specimen that apparently represents the inner whorls of the same species. This has many of the ribs once bifurcate, the others simple.

The following is a translation of the original description of the species:

Shell discoidal, spire composed of embracing whorls of nearly round cross section, visible in the umbilicus in a third of its width, having its major thickness near the umbilical border; flanks convex, descending gradually toward the umbilicus; siphonal region perfectly rounded. Umbilicus small, rather deep, its border not angulated. Surface covered with 46 to 48 strong, equal costellæ which bifurcate, some at the middle of the flanks and others a little earlier; of the former some trifurcate and the latter undergo a second bifurcation, which takes place at the same distance from the umbilicus as that of the other costellæ; three or four ribs remain simple; all cross the siphonal region forming a slight forward inflection. Aperture a little higher than wide, a little invaded by the whorl of the spire and rounded above. Three narrow constrictions [*surcos*] are seen, shallow and parallel to the costellæ. Diameter 60 mm., 75 mm.; breadth [height] of the last whorl with relation to the diameter 0.38, 0.38; thickness of the last whorl with relation to the diameter 0.38, 0.38; diameter of the umbilicus with relation to the diameter 0.35, 0.33.

### PERISPHINCTES SCHUCHERTI sp. n.

Pl. XXV, fig. 1; Pl. XXVI, figs. 1–3; Pl. XXVII, fig. 1.

Shell discoidal, moderately involute, each whorl embracing about a third of its predecessor: the umbilicus strongly excavated, its span equaling about a third of the corresponding diameter of the shell: whorls laterally compressed, even the earlier ones being much higher than wide, the flanks flattened-convex, narrowed toward the siphonal side, which is rounded, umbilical border rounded above, descending almost sheerly below to the surface of the inner whorls; septal line with two lateral lobes, of which the first is large, ample-trunked and longer than the siphonal lobe, and ends in three branches, the second lateral lobe being well developed and considerably more than half as long as the first, suspensive lobe (*nahtlobus*) of intermediate steepness, presenting one conspicuously large auxiliary lobe; ribs gently

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inclined forward on the flanks, somewhat enlarged on the umbilical border, those of the earlier whorls very close and bifurcating or sometimes trifurcating at about the middle of the flank into feebly diverging smaller ones, an occasional rib remaining simple and then being usually accompanied by a short, independent rib, corresponding with one of those produced by bifurcation, this ornamentation becoming gradually obsolete on the greater part of the height of the flanks and also on a narrow median zone in the more mature portion of the shell, which portion is also usually encircled with large shallow constrictions at remote intervals; the ventral ribs about equal to the intervals between them.

*Measurements.*—The maturer aspects of the shell are represented only by fragments; the cross section of one of which has a height of 47 mm. and a breadth of 27 mm.

*Occurrence.*—The type material consists of several imperfect specimens and various fragments, all collected by Doctor Stanton in foothills near the railroad, at the northwest end of Malone Mountain, about 2 miles east-southeast of Finlay station. Material obtained on the west side of Malone Mountain, from No. 13 of Malone Mountain section, includes a very doubtful fragment of this species from about 2 miles west of Malone station, and a specimen, also doubtful, and a fragment from a point about three-fourths of a mile farther south. That collected 1½ miles east of Malone station includes a fragment which not improbably belongs to this species.

The septal line of *P. schucherti* is of the same general pattern as that of *P. inconditus* Font., as figured by de Loriol,[a] but differs from it by its broader first lateral lobe and in other details. The shell of *P. schucherti* also differs from that of *P. inconditus* in that the latter has trifurcate and even sometimes quadrifurcate ribs, the ribbing on the flanks of the inner whorls being very much closer in *P. schucherti* than in either *inconditus* or *balderus*.

The second specimen above mentioned is larger and less compressed than the others and has the ribs less inclined forward on the venter, and on part of the shell almost radially directed. I am uncertain whether it belongs to *P. schucherti* or is the young of a larger species. The ribs are, however, obsolete on the flanks, and the specimen is therefore referred here provisionally. It gives the following measurements: Greatest diameter, 125 mm.; span of umbilicus, 50 mm.; height of outer whorl in intermediate part, 45 mm.; breadth of same, 30 mm. It is without constrictions, and in form and character of ventral ribbing bears a resemblance to *Olcostephanus potosinus* C. and A., a fossil from which in other respects it widely differs.

The species is named for Mr. Charles Schuchert, curator of invertebrate paleontology in the United States National Museum.

[a] Foss. d. Baden, Pl. XI, fig. 1c.

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## Genus ASPIDOCERAS Zittel.

### ASPIDOCERAS ALAMITOCENSIS C. and A.

Pl. XXVII, fig. 2.

*Aspidoceras alamitocensis* Castillo and Aguilera, 1895, Bol. Com. Geol. Mex., No. 1, p. 43, Pl. XXIII.

A portion of a shell which appears quite identical with this bulky ammonite was obtained 1½ miles east of Malone station. It includes about a fourth of a volution, belonging mostly to the septate part of the shell, but including also a small posterior fraction of the body chamber. The septal line is imperfectly shown, but the lateral lobes and saddles are large and coarsely dissected, the saddles having obtuse, the lobes having sharply pointed terminal divisions; and the auxiliaries (not visible in our specimen) are few, or at least not present beyond a narrow umbilical tract of the whorl. Of the two rows of tubercles, only one—that which borders the umbilicus—is shown, owing to the condition of the specimen. Traces of low ribs separated by broad and shallow valleys and crossing the broadly rounded outer side of the whorl, are distinguishable. The specimen indicates a shell at least as large as the largest of the Alamitos specimens whose dimensions are given by Castillo and Aguilera. In the matrix with it are several imperfect specimens of *Exogyra subplicifera.*

# VERTEBRATA.

As compared with the rich invertebrate fauna, the known vertebrate fauna of the Malone formation is pitifully meager.

Besides a few ill-preserved and problematical structures which may pertain to Vertebrata, the Malone Hills, 1½ miles east of Malone station, have yielded two cycloid fish scales, between circular and quadrate in outline and a little smaller in area than a 1-cent piece; one well-preserved hemispherical tooth, about the size of a checkerberry, of a Pycnodont; and a number of fragments of bones of rather large swimming reptiles, which are probably in part those of Enaliosaurs.

The east slope of Malone Mountain, a mile north of its southern end, has yielded Doctor Stanton a shark's spine of indeterminate genus.

While the Upper Jurassic rocks of Potosi, Oaxaca, etc., Mexico, have yielded a considerable number of invertebrates—some now known, others not yet known, from Texas—they have apparently yielded no vertebrate remains of record whatsoever; and the above brief notices therefore apparently embrace all that is known of the Vertebrata of the Upper Jurassic in Texas and Mexico.

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# PLATES.



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# PLATE II.



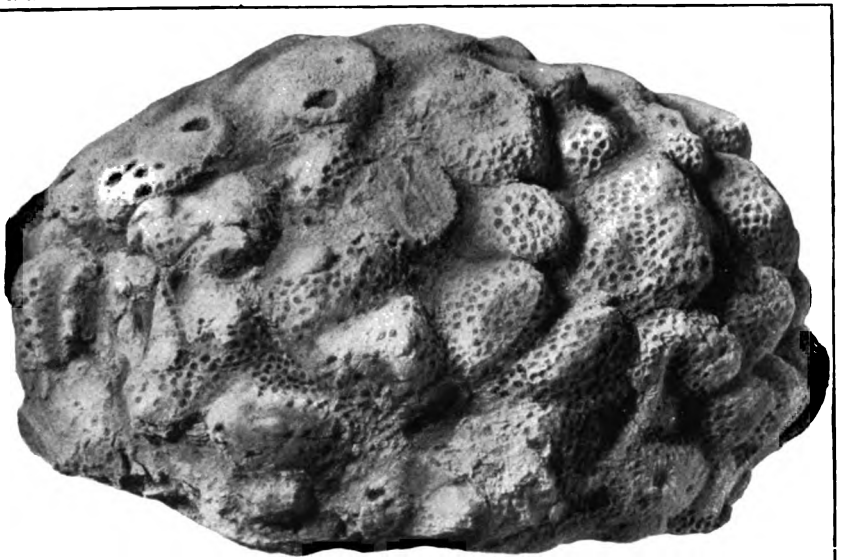
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# PLATE II.

FIGS. 1–3. ASTROCŒNIA MALONIANA Vaughan, sp. n. (p. 34).
Figs. 2, 3. Coralla of natural size showing variation in mode of growth.
Fig. 3. Several corallites from fig. 2, enlarged 6 diameters.
FIG. 4. SERPULA sp. (p. 37).
Cross sections of tubes.
FIGS. 5, 6. SERPULA GORDIALIS Schlotheim (p. 37).
Several specimens growing on Astrocœnia maloniana.
FIG. 7. BERENICEA MALONIANA sp. n. (p. 38).
Enlarged 3 diameters.



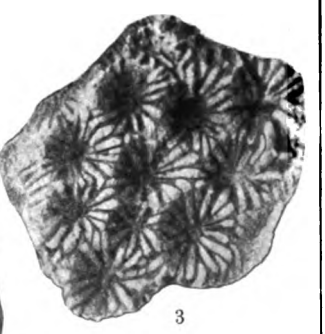
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# PLATE III.



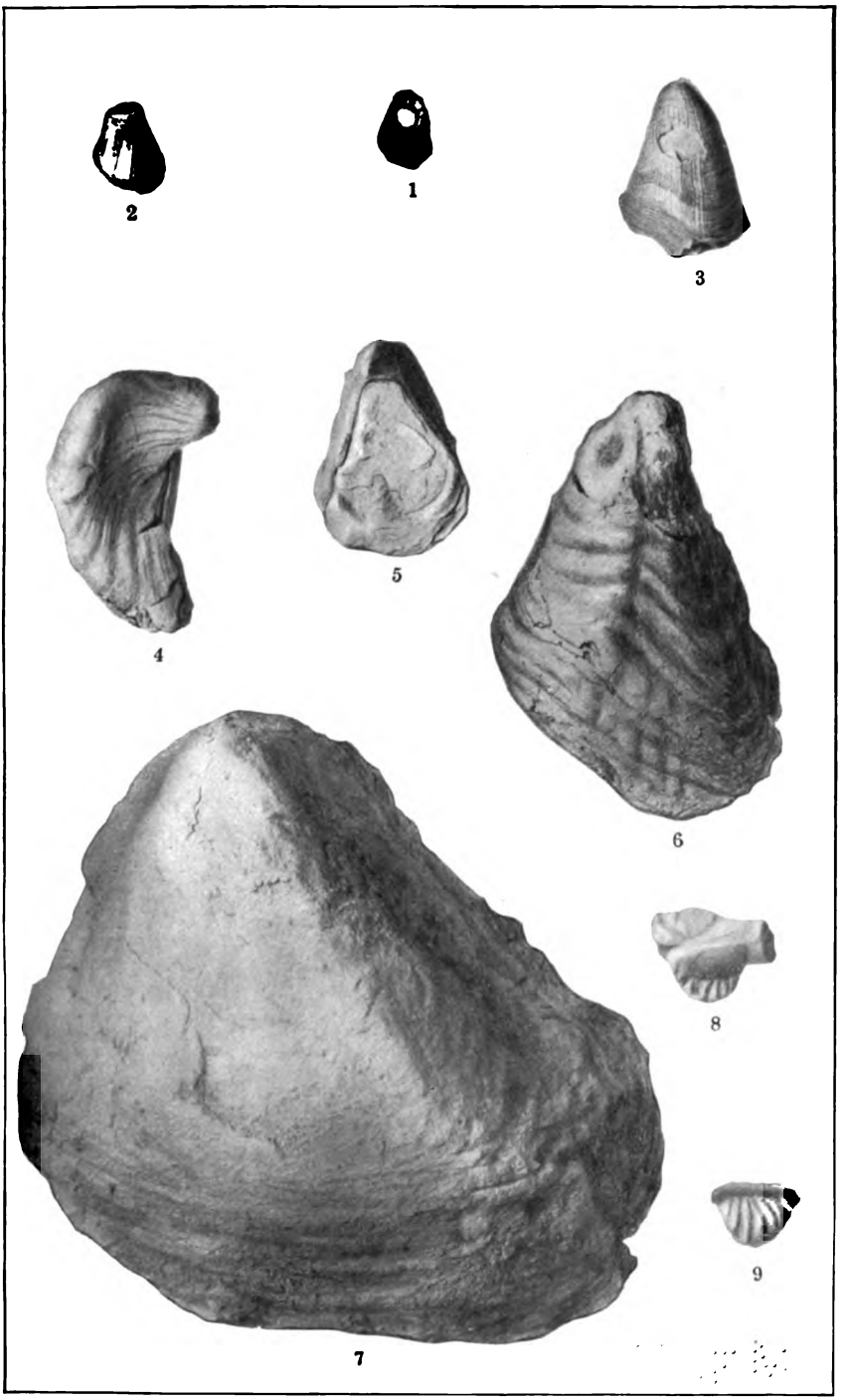
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# PLATE III.

FIGS. 1–6. GRYPHÆ MEXICANA Felix (p. 39).
Fig. 1. Young specimen, natural size.
Fig. 2. Young striated individual, enlarged 1½ diameters.
Figs. 4–6. Mature specimen.
FIG. 7. EXOGYRA POTOSINA Castillo and Aguilera (p. 41).
See Pl. IV for additional figure.
FIGS. 8, 9. PLICATULA SPORTELLA sp. n. (p. 43).
Two views of the imperfect type specimen.



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# PLATE IV.



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# PLATE IV.

FIGS. 1–4. EXOGYRA SUBPLICIFERA Felix (p. 41).

FIGS. 5, 6. LIMA INTERLINEATA sp. n. (p. 43).

Fig. 5. Type specimen, natural size.

Fig. 6. Part of sculpture, enlarged 3 diameters.

FIG. 7. EXOGYRA POTOSINA Castillo and Aguilera (p. 41).

See Pl. III, fig. 7.

FIGS. 8, 9, 10. GERVILLIA CORRUGATA sp. n. (p. 46).

Fig. 8. Right valve with most of the shell exfoliated.

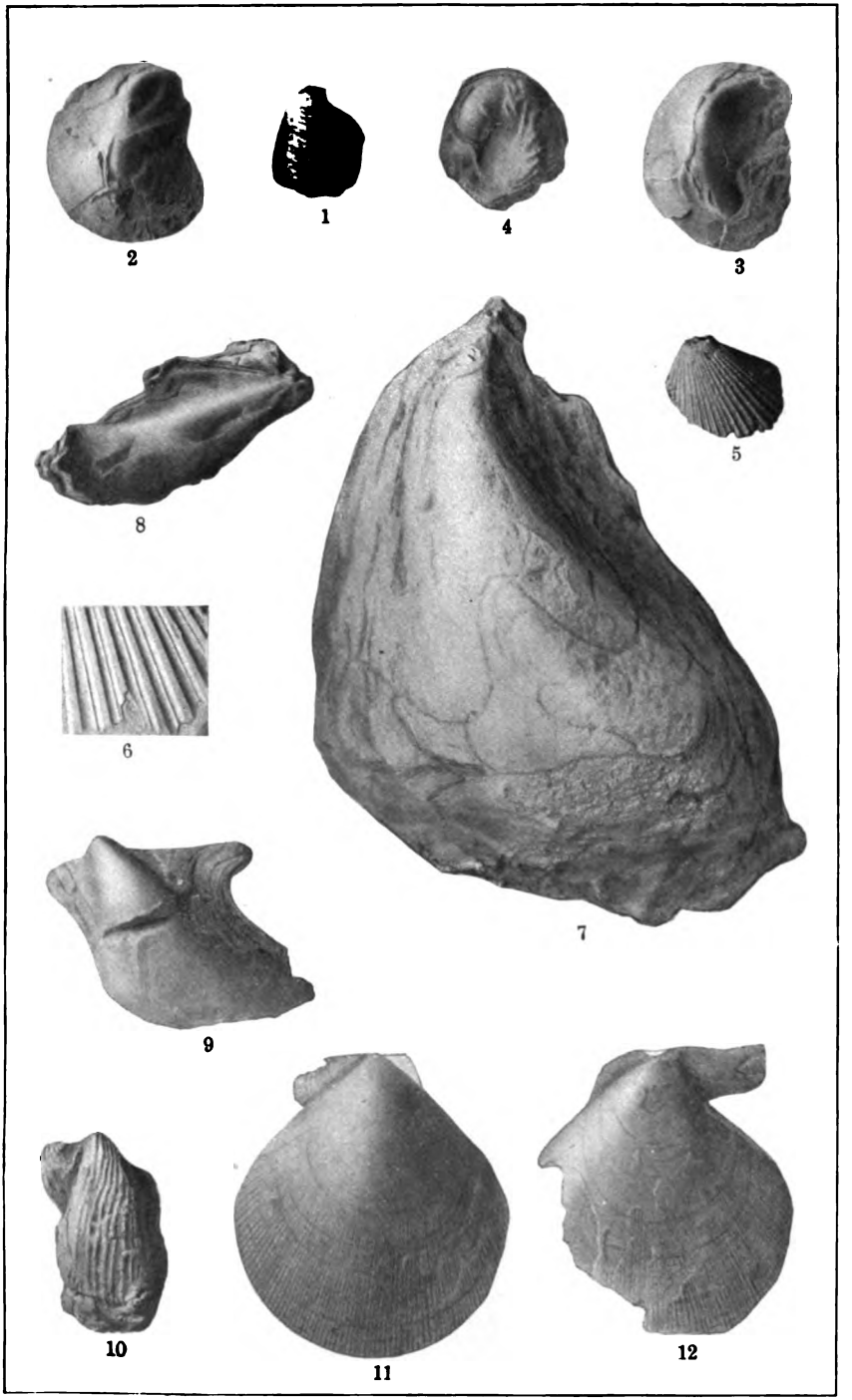
Fig. 9. Left valve of another specimen in same state of preservation.

Fig. 10. Small distorted left valve showing strong sculpture of umbo.

FIGS. 11, 12. PECTEN INSUTUS sp. n. (p. 44).



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# PLATE V.



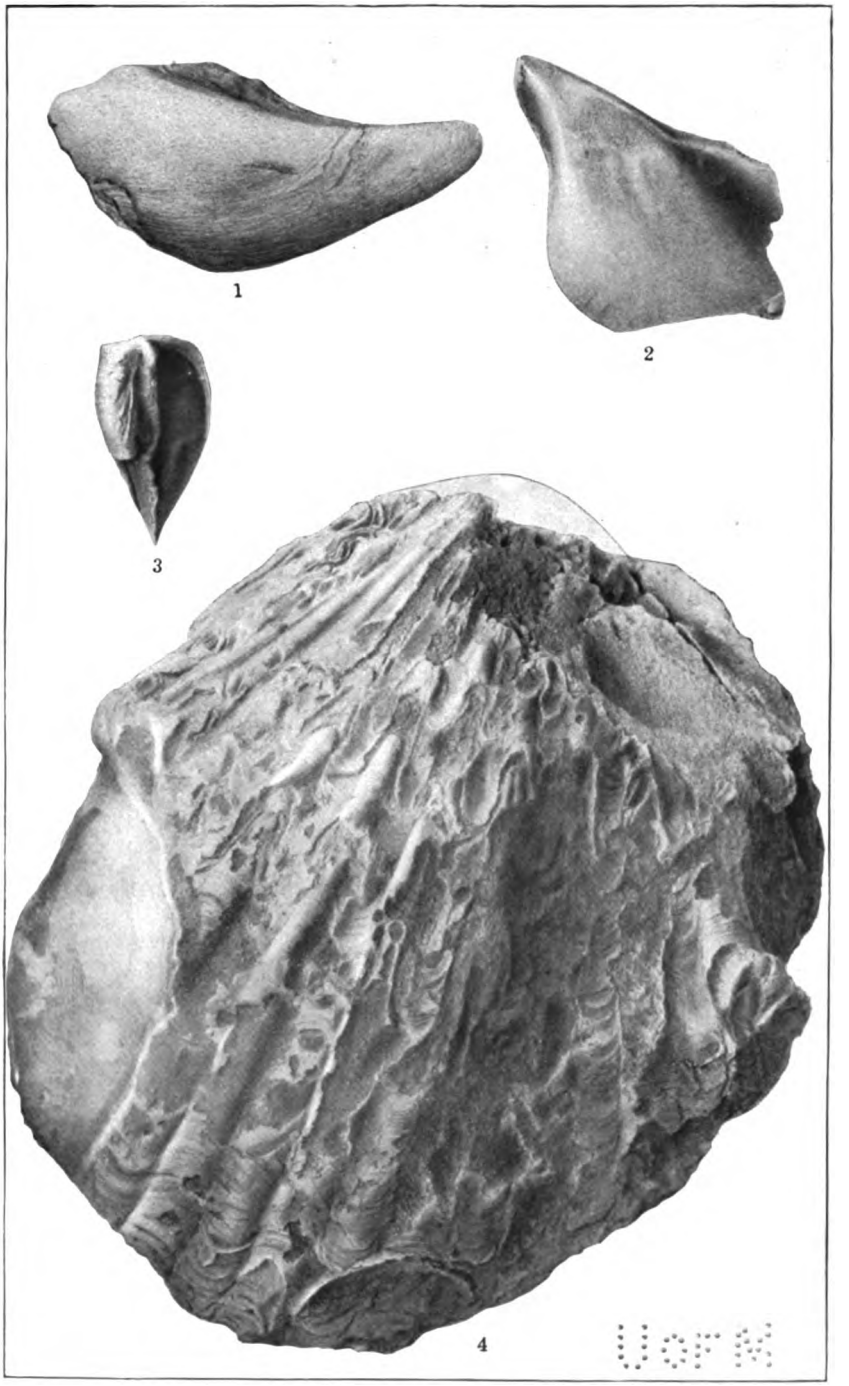
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# PLATE V.

FIG. 1. GERVILLIA CINDERELLA sp. n. (p. 47).
FIGS. 2, 3. GERVILLIA ? RIOGRANDENSIS sp. n. (p. 47).
Side and profile views of the type specimen.
FIG. 4. LIMA (CTENOSTREON) RIOGRANDENSIS sp. n. (p. 44).



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# PLATE VI.



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# PLATE VI.

FIGS. 1, 2. MODIOLA MALONIANA sp. n. (p. 48).
Side and profile views of the type specimen.
FIG. 3. MODIOLA GENICULATA sp. n. (p. 49).
FIGS. 4, 5. MYTILUS NUNTIUS sp. n. (p. 48).
Side and profile views of the type specimen.
FIG. 6. ARCA DUMBLI sp. n. (p. 51).
FIGS. 7, 8. ARCA TAFFII sp. n. (p 50).
Side and profile views of the type specimen.
FIGS. 9, 10. CUCULLÆA ? TEXICOSTATA sp. n. (p 52).
Fig. 9. The imperfect type specimen.
Fig. 10. Portion of surface enlarged.
FIGS. 11, 12. CUCULLÆA CASTILLOI sp. n. (p 54).
Side and profile views of the type specimen.
FIG. 13. LEDA ? NAVICULA sp. n. (p. 55).



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# PLATE VII.



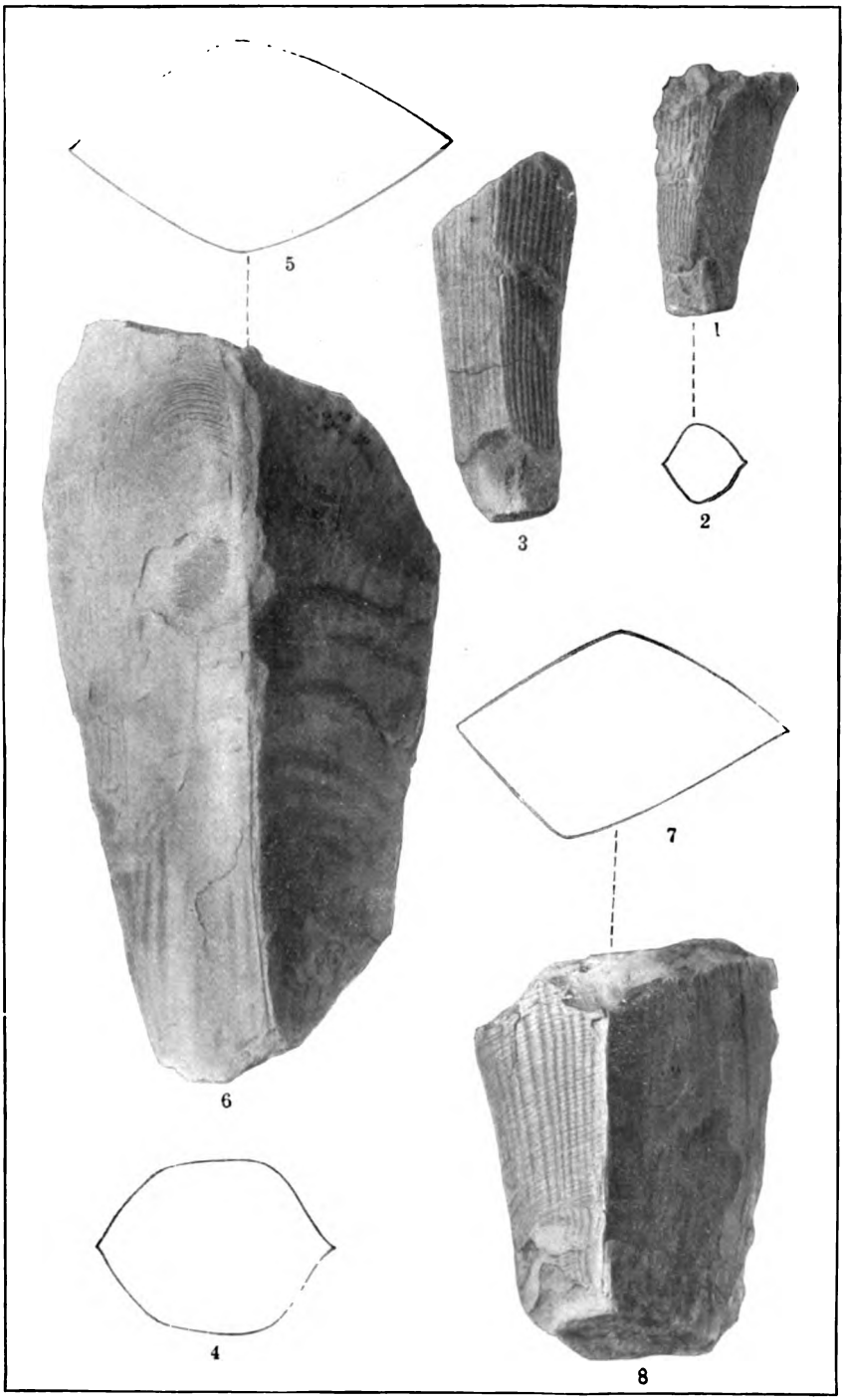
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# PLATE VII.

FIGS. 1–8. PINNA QUADRIFONS sp. n. (p. 49).



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# PLATE VIII.



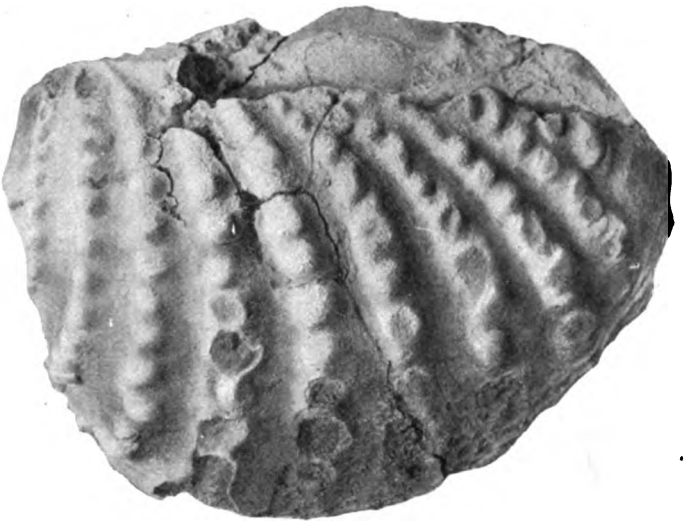
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# PLATE VIII.

FIGS. 1, 2. TRIGONIA VYSCHETZKII Cragin (p. 56).
See Pl. IX, fig. 3, for anterior view of specimen represented by fig. 1.



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# PLATE IX.



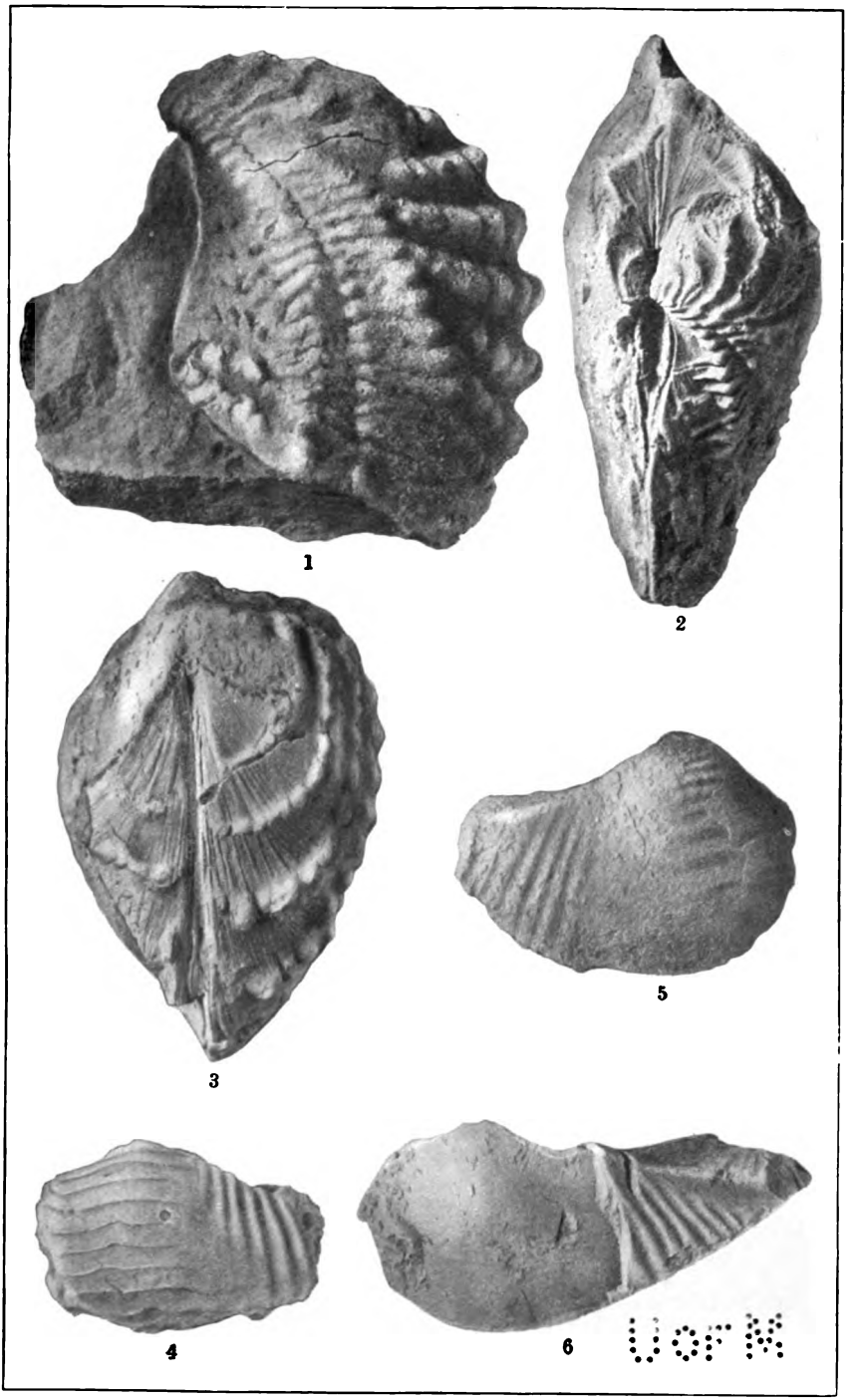
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# PLATE IX.

FIGS. 1–3. TRIGONIA VYSCHETZKII Cragin (p. 56).
See Pl. VIII, fig. 1, for side view of fig. 3.
FIGS. 4–5. TRIGONIA CALDERONI (Castillo and Aguilera) (p. 59).



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# PLATE X.



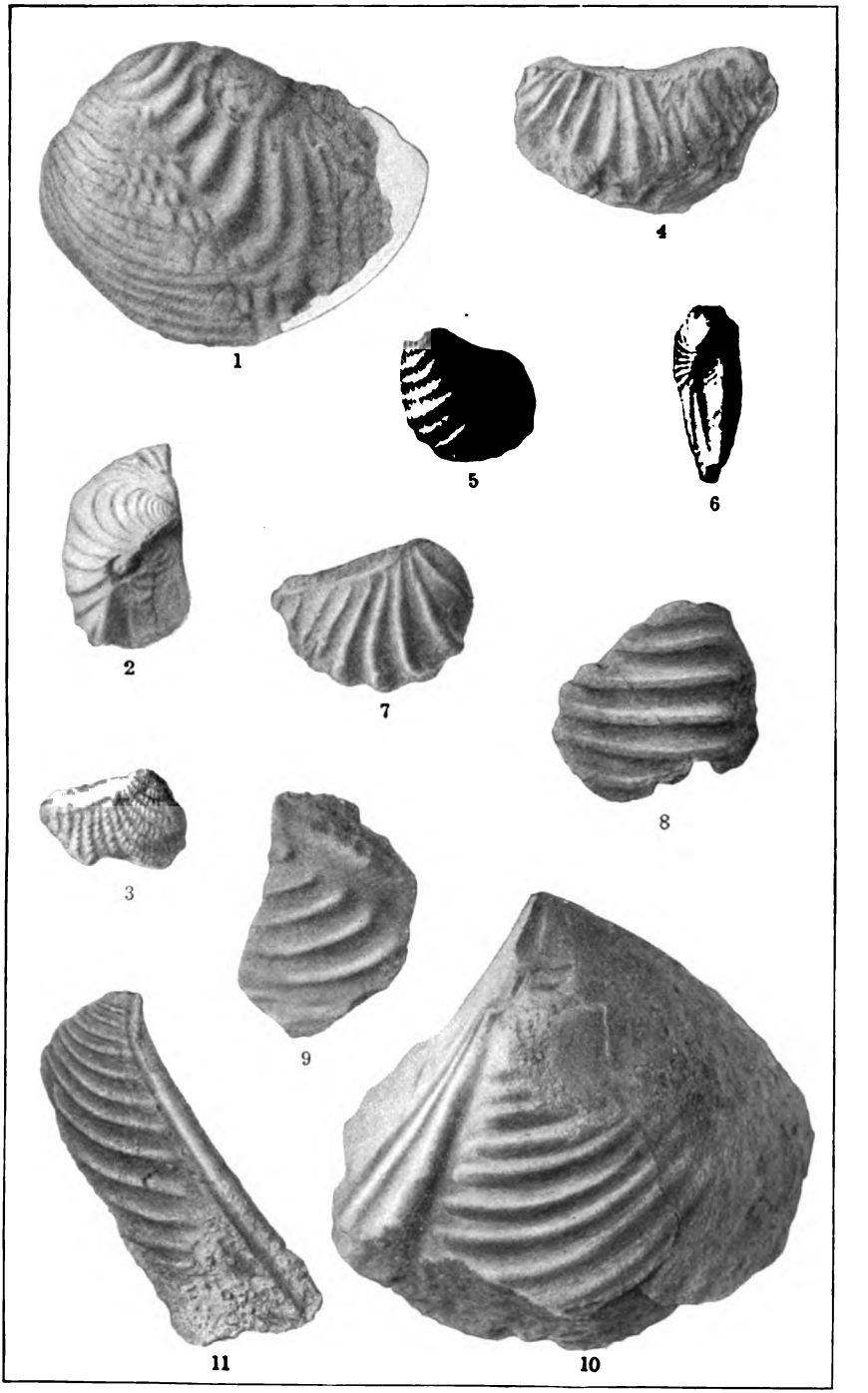
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# PLATE X.

FIGS. 1, 2. TRIGONIA GOODELLII Cragin (p. 58).
FIGS. 3–6. TRIGONIA PROSCABRA sp. n. (p. 60).
FIG. 7. TRIGONIA PRÆSTRIATA sp. n. (p. 61).
FIGS. 8–11. TRIGONIA MUNITA sp. n. (p. 62).



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# PLATE XI.



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# PLATE XI.

FIGS. 1, 2. TRIGONIA RUDICOSTATA sp. n. (p. 63).
Side and profile views of the type specimen.

FIG. 3. TRIGONIA CONFERTICOSTATA sp. n. (p. 63).

FIG. 4. ASTARTE BREVIACOLA sp. n. (p. 64).

FIGS. 5, 6. ASTARTE POSTICALVA sp. n. (p. 67).
Fig. 5. Left valve of type enlarged 2 diameters.
Fig. 6. Dorsal view of another specimen.

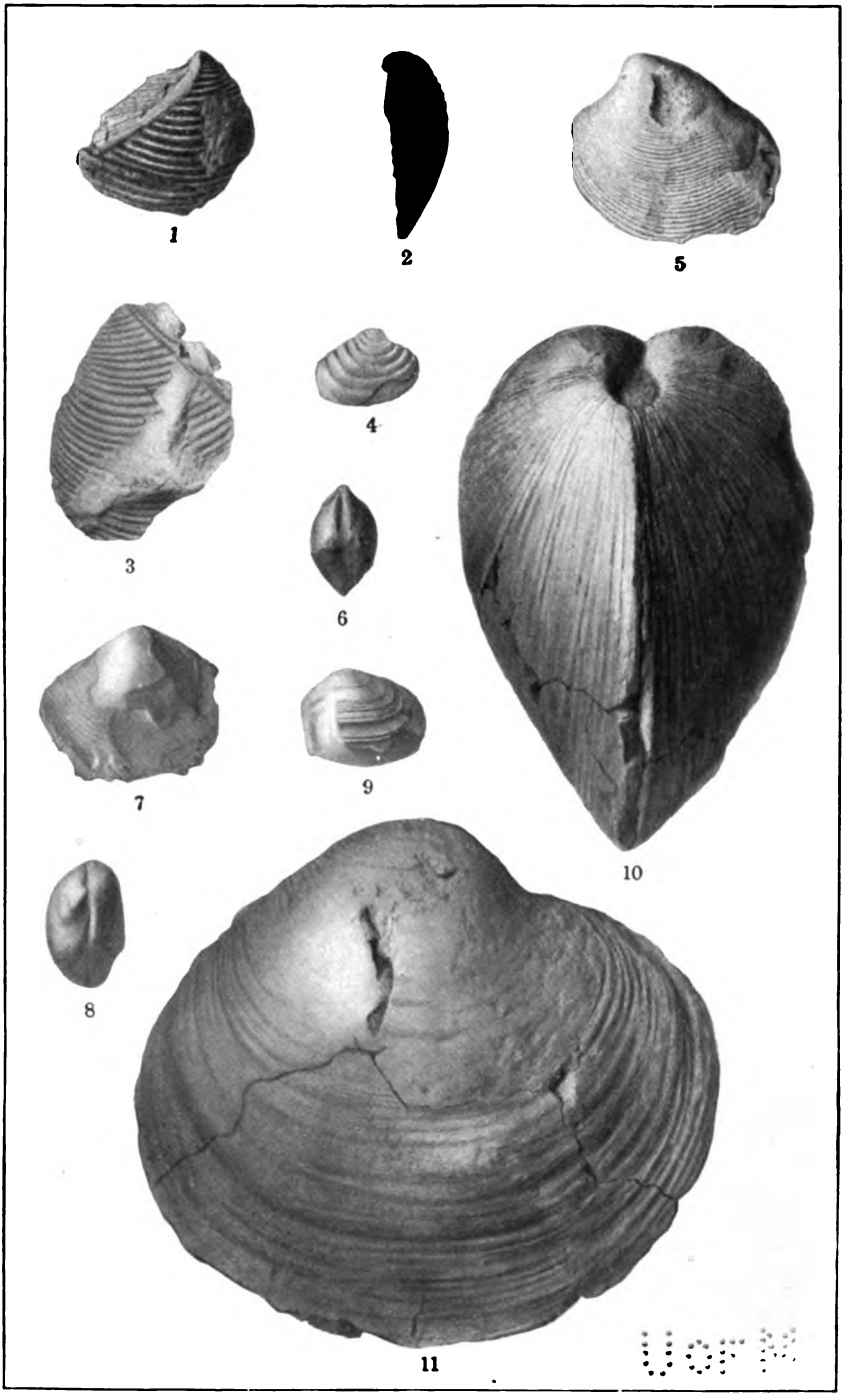
FIG. 7. ASTARTE CRATICULA sp. n. (p. 68).

FIGS. 8, 9. ASTARTE? ISODONTOIDES sp. n. (p. 67).

FIGS. 10, 11. ASTARTE MALONENSIS Cragin (p. 65).
See Pl. XII for additional figures.



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# PLATE XII.



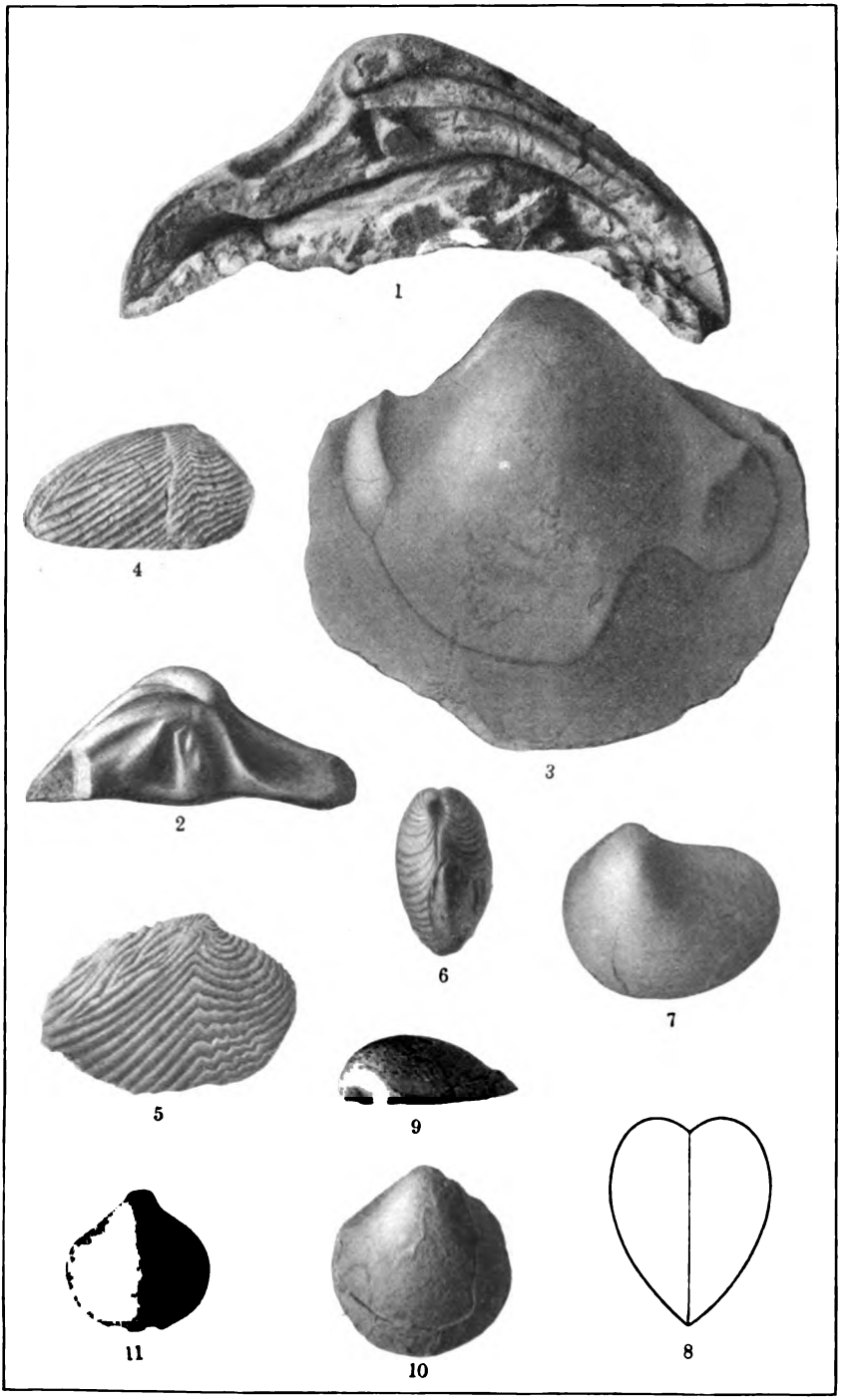
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# PLATE XII.

FIGS. 1–3. ASTARTE MALONENSIS Cragin (p. 65).
See Pl. XI for additional figures.
FIGS. 4–6. PTYCHOMYA STANTONI sp. n. (p. 69).
Fig. 4. Natural size.
Figs. 5, 6. Another specimen enlarged 1½ diameters.
FIGS. 7, 8. UNICARDIUM ? TRANSVERSUM sp. n. (p. 76).
FIGS. 9–11. UNICARDIUM ? SEMIROTUNDUM sp. n. (p. 76).



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# PLATE XIII.



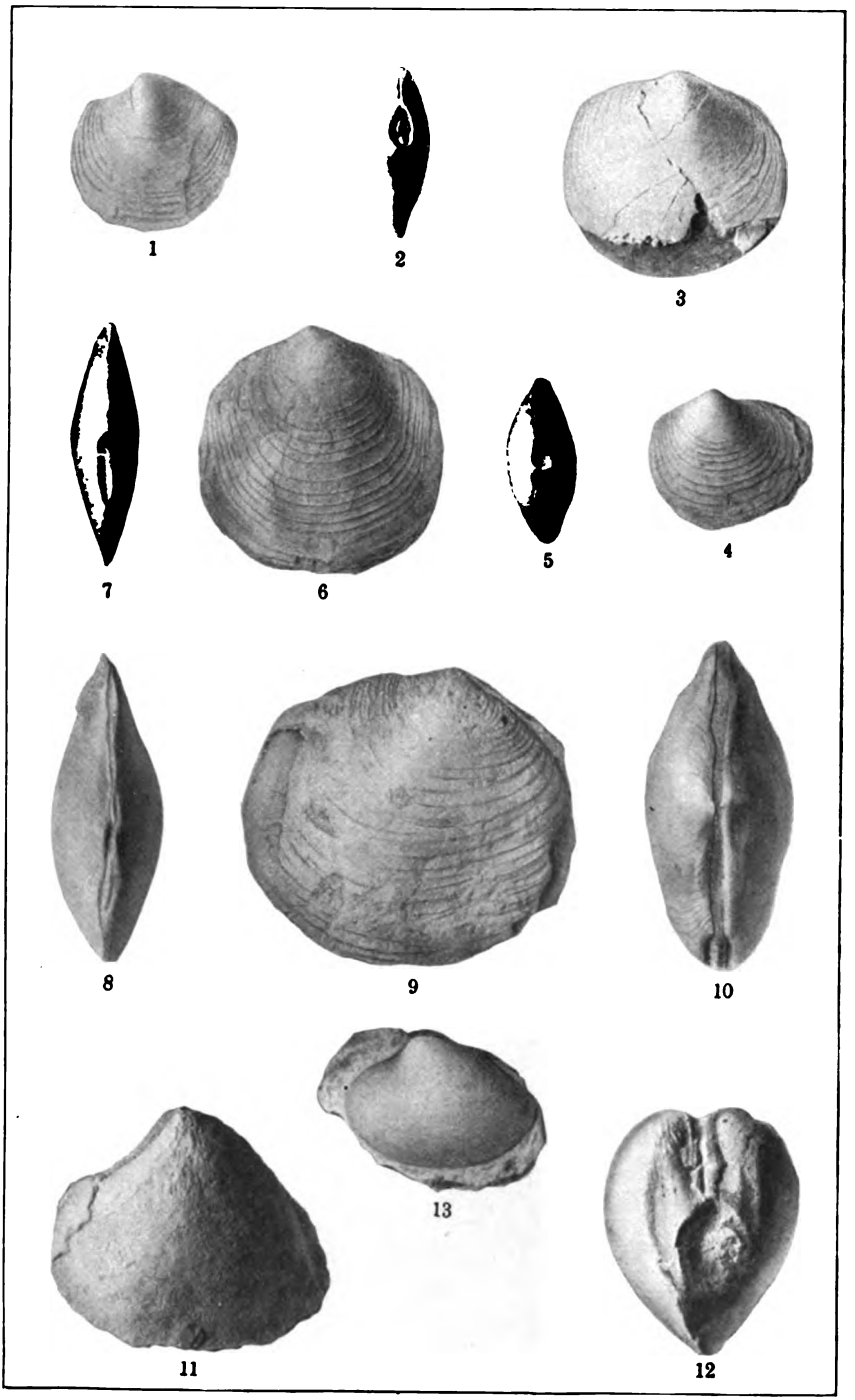
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# PLATE XIII.

FIGS. 1, 2. CYPRINA STREERUVITZII Cragin (p 78).
FIG. 3. LUCINA PLANIUSCULA sp. n. (p. 75).
FIGS. 4, 5. LUCINA POTOSINA Castillo and Aguilera (p. 72).
FIGS. 6–10. LUCINA POTOSINA var. metrica var. n. (p. 73).
FIGS. 11, 12. CYPRINA COTEROI Castillo and Aguilera (p. 77).
FIG. 13. TAPES CUNEOVATUS sp. n. (p. 79).



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# PLATE XIV.



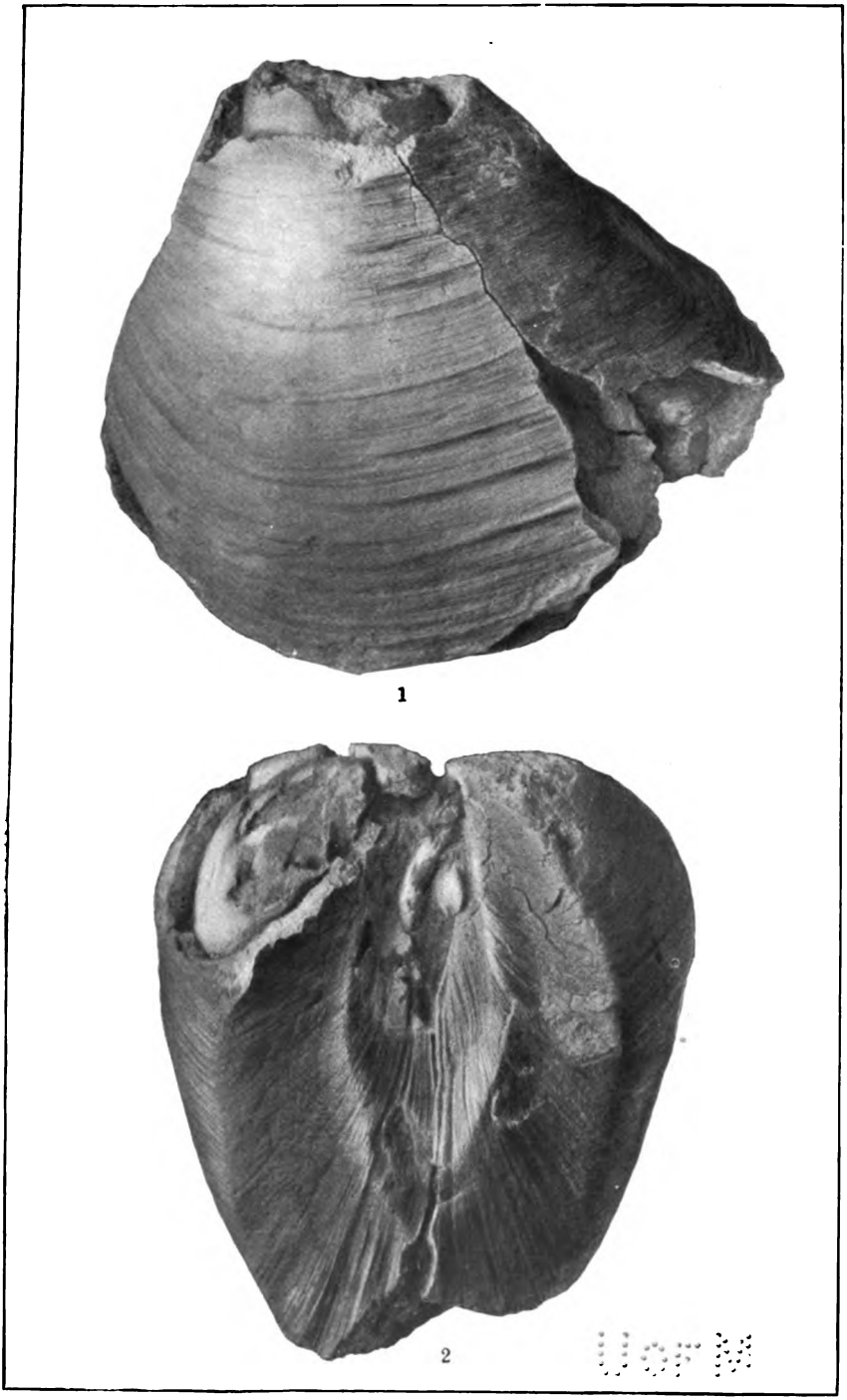
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# PLATE XIV.

FIGS. 1, 2. CYPRINA STREERUVITZII Cragin (p. 78).
Two views of type specimen in collection of Geological Survey of Texas. See Pl. XV, fig. 1, for additional figures of same specimen.



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# PLATE XV.



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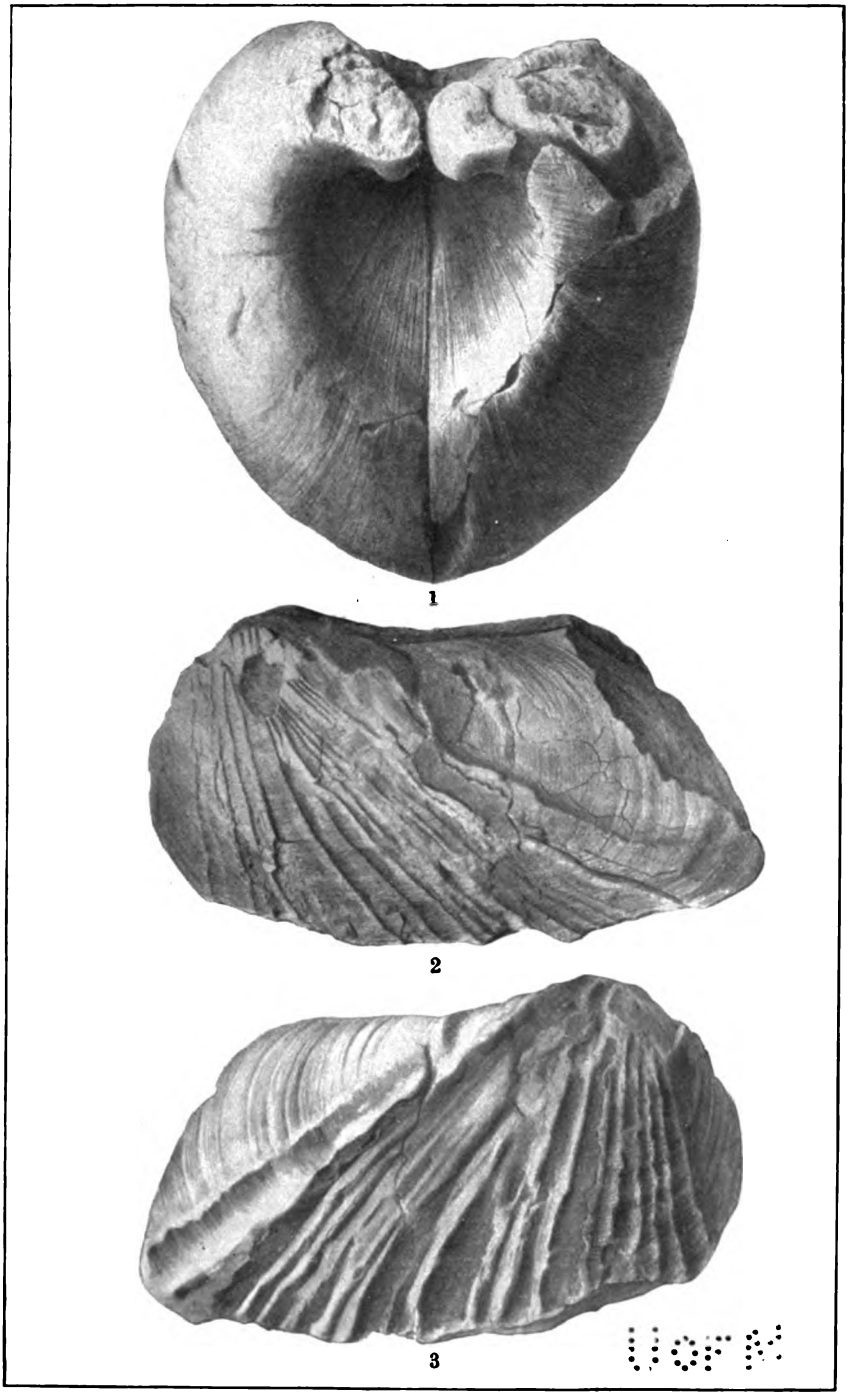
# PLATE XV.

FIG. 1. CYPRINA ? STREEBUVITZII Cragin (p. 78).
See Pl. XIV for other views of same specimen.

FIGS. 2, 3. PHOLADOMYA TOSTA sp. n. (p. 79).
Opposite views of the same specimen.



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# PLATE XVI.



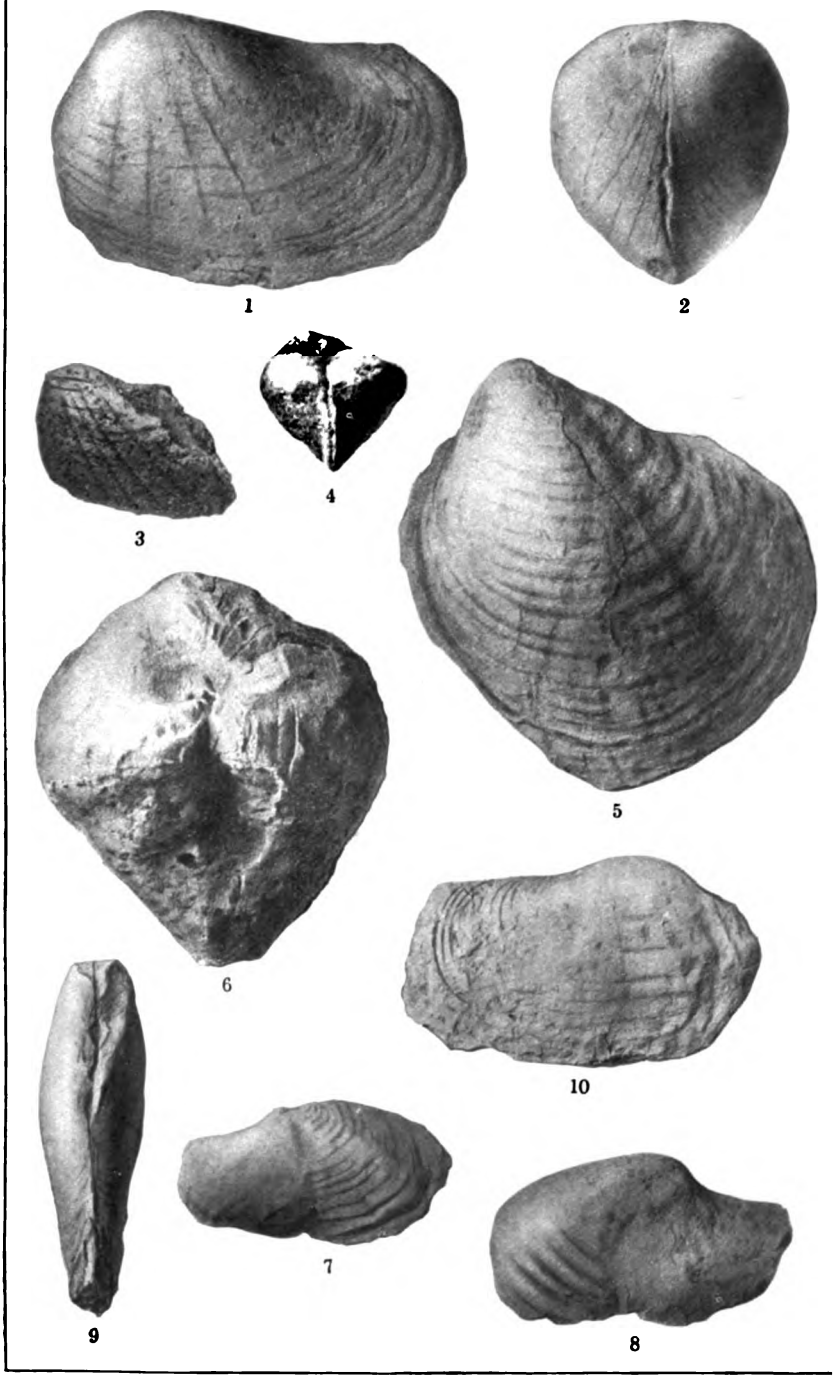
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# PLATE XVI.

FIGS. 1, 2. PHOLADOMYA MARCOUI sp. n. (p. 80).
Side and anterior views of the same specimen.
FIGS. 3, 4. PHOLADOMYA PRÆPOSITA sp. n. (p. 82).
Two views of the same specimen.
FIGS. 5, 6. PHOLADOMYA PAUCICOSTA Roemer? (p. 81).
Side and dorsal views of the same specimen.
FIGS. 7, 8. ANATINA OBLIQUIPLICATA sp. n. (p. 85).
FIGS. 9, 10. ANATINA ? PLICULIFERA sp. n. (p. 86).



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# PLATE XVII.



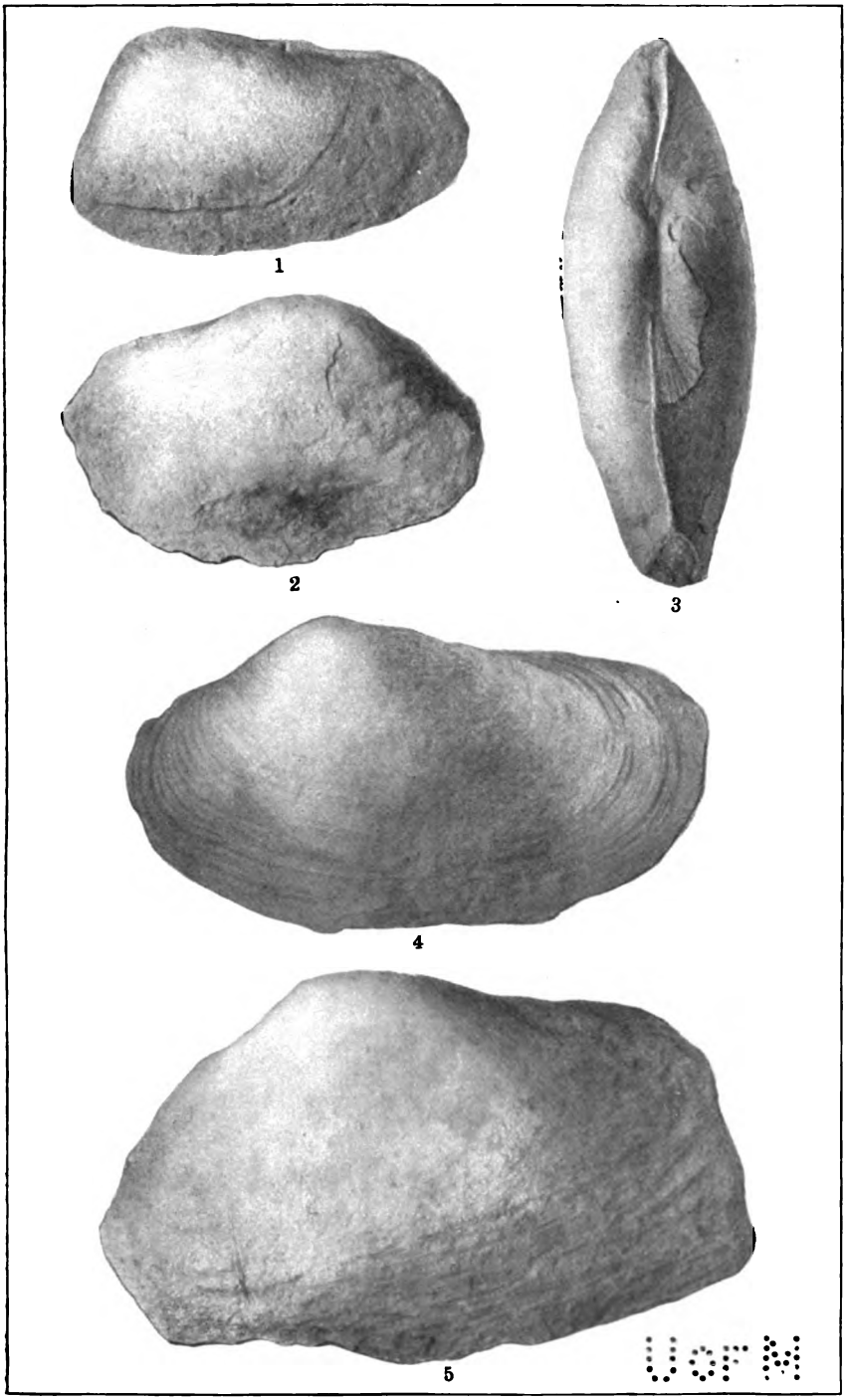
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# PLATE XVII.

FIGS. 1–5. PLEUROMYA INCONSTANS Castillo and Aguilera (p. 82). See Pl. XVIII for additional figures.



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# PLATE XVIII.



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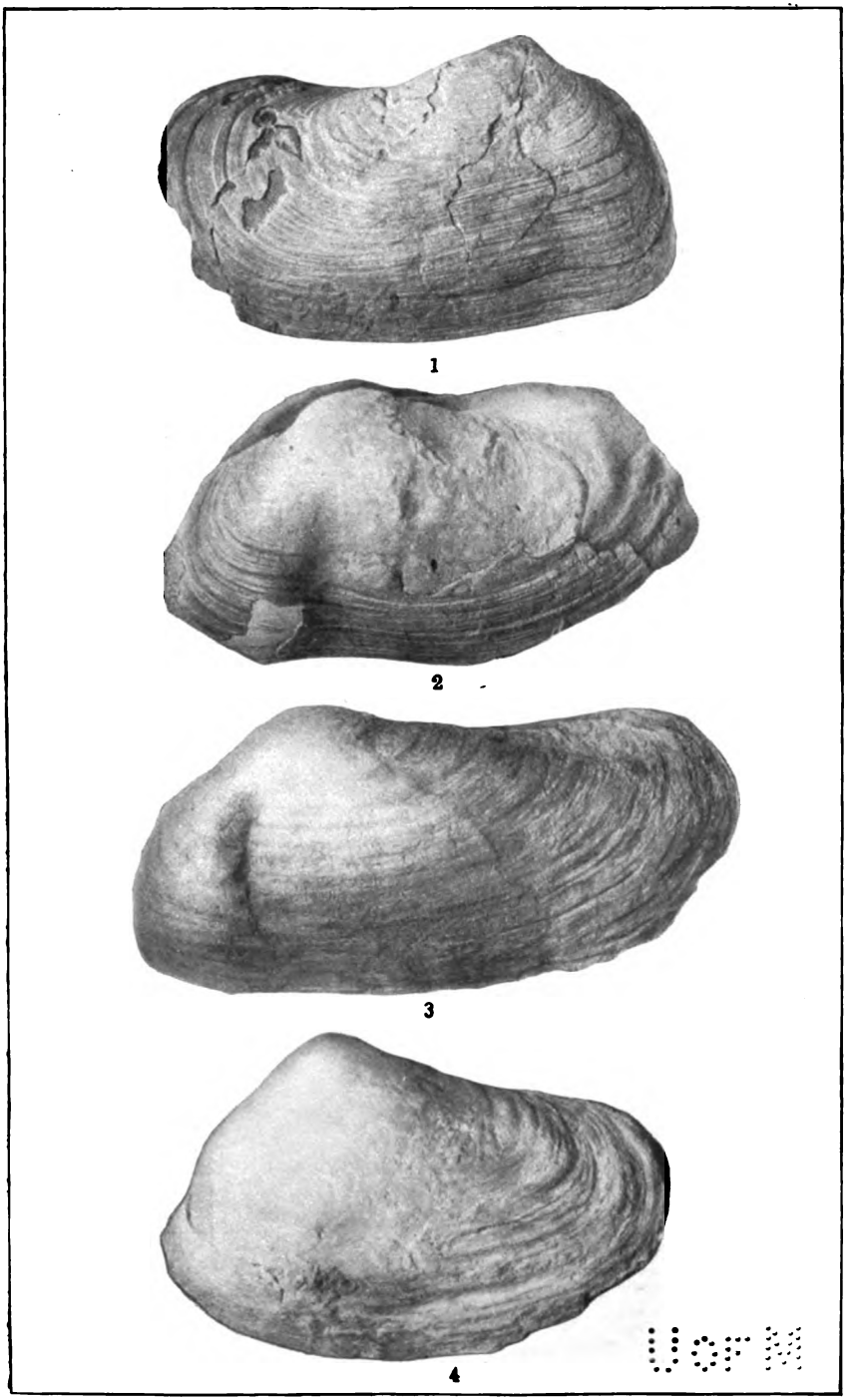
# PLATE XVIII.

FIGS. 1–3. PLEUROMYA INCONSTANS Castillo and Aguilera (p. 82).
See Pl. XVII for additional figures.

FIG. 4. PLEUROMYA INCONSTANS var. curta var. n. (p. 84).
See Pl. XIX for additional figures.



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# PLATE XIX.



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# PLATE XIX.

FIGS. 1, 2. PLEUROMYA INCONSTANS var. curta var. n. (p. 84).
See Pl. XVIII for additional figure.

FIGS. 3–5. MARTESIA MALONIANA sp. n. (p. 87).
Figs. 3, 4. Side and dorsal views of the same specimen.
Fig. 5. Anterior view of another specimen.

FIG. 6. THRACIA ? MALONIANA sp. n. (p. 86).

FIG. 7. CORBULA MALONIANA sp. n. (p. 87).

FIGS. 8, 9. PLEUROTOMARIA CIRCUMTRUNCA sp. n. (p. 88).
Two views of the same specimen.

FIGS. 10, 11. TURBO BENECLATHRATA sp. n. (p. 88).
Two views of the type.

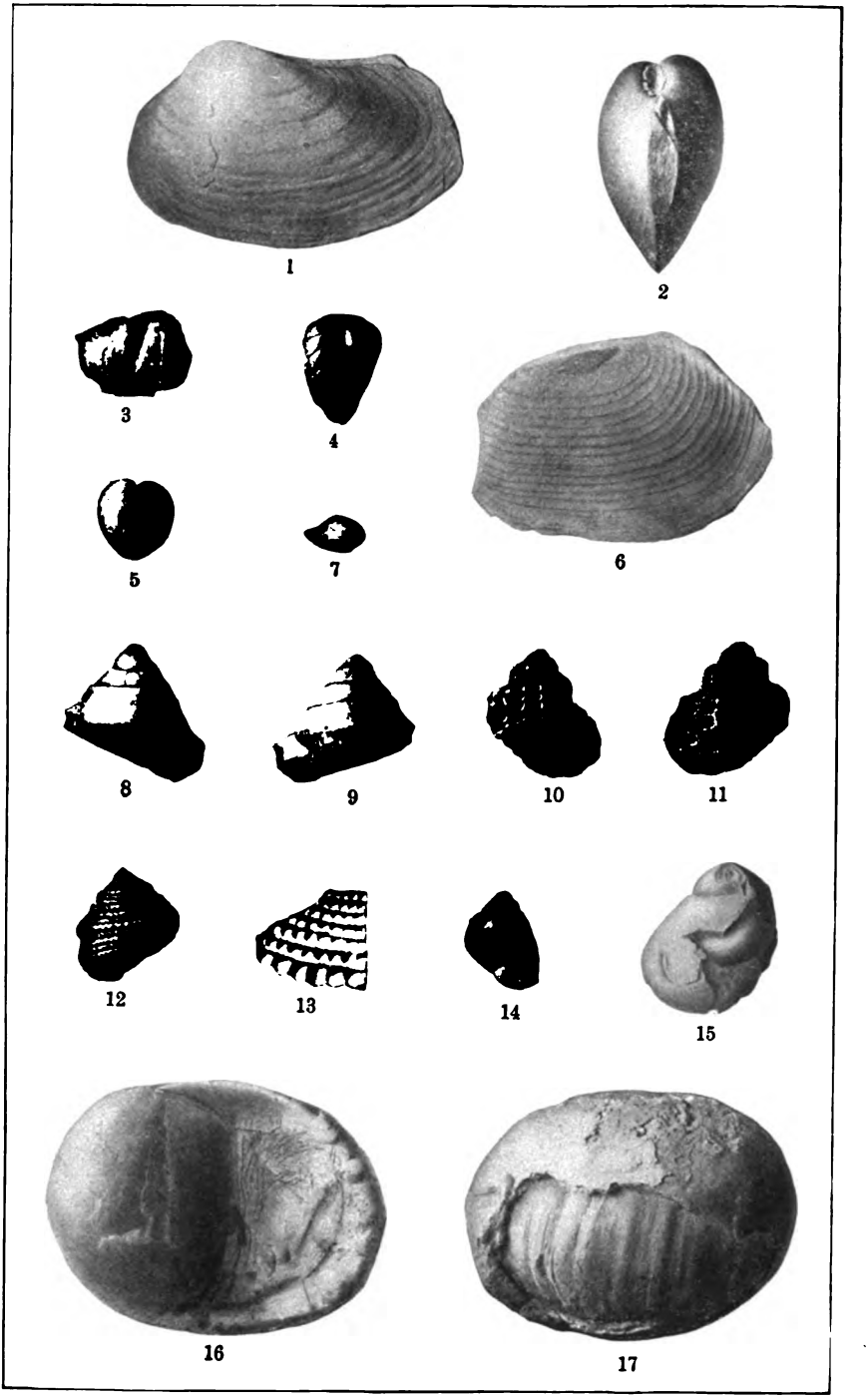
FIGS. 12–14. DELPHINULA STANTONI sp. n. (p. 89).
Fig. 12. Dorsal view slightly restored.
Fig. 13. Enlargement of part of surface sculpture of same specimen.
Fig. 14. Aperture view of a small weathered specimen.

FIG. 15. NERITA FINLAYENSIS sp. n. (p. 90).

FIGS. 16, 17. NERITA PEROBLATA sp. n. (p. 91).
Two views of the type.



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# PLATE XX.



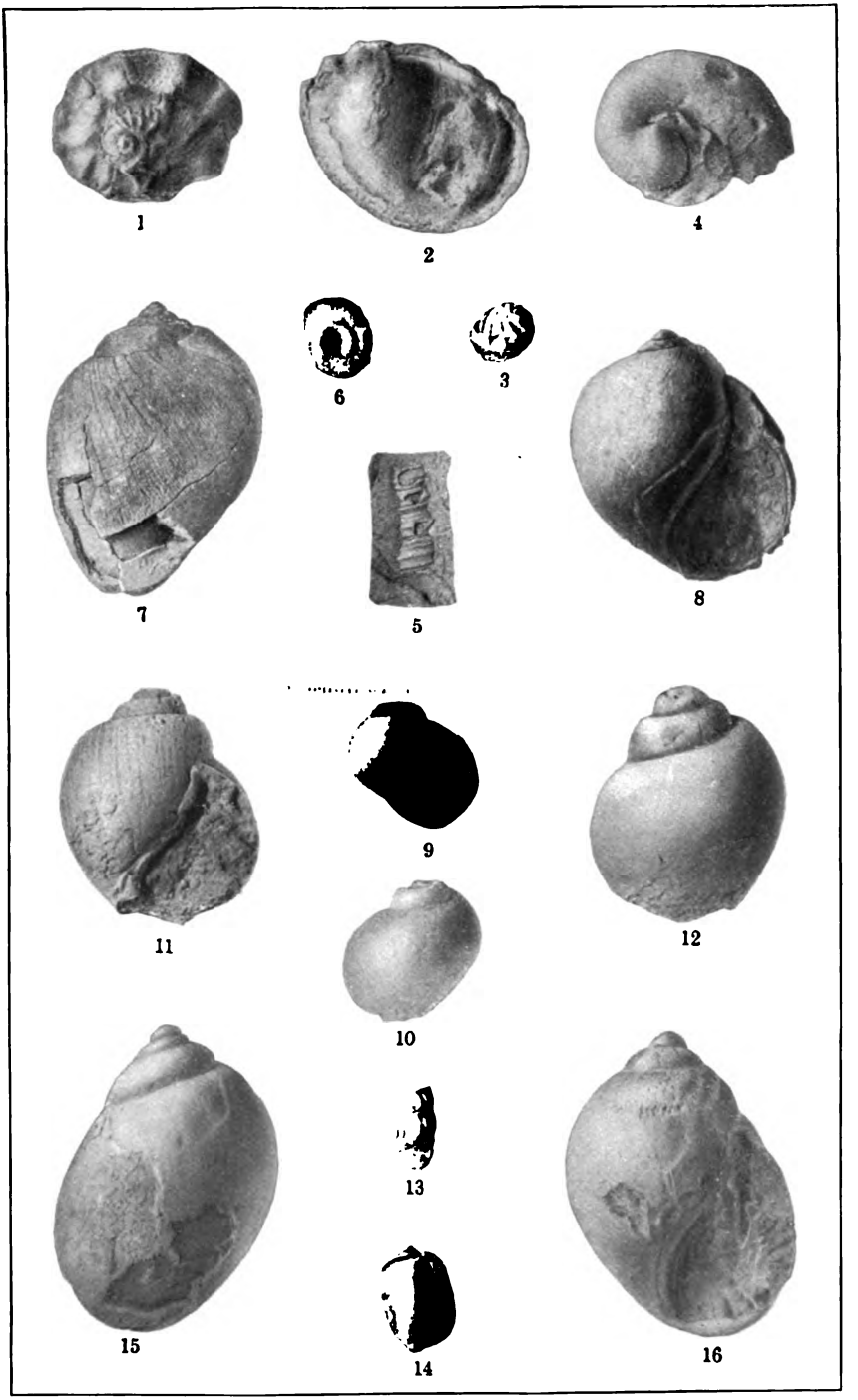
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# PLATE XX.

FIGS. 1–4. NERITA NODILIRATA sp. n. (p. 90).
Fig. 1. Apical view of a medium specimen.
Fig. 2. Aperture view of another specimen viewed obliquely from the base so that the spire is concealed.
Fig. 3. Dorsal view of a young individual.
Fig. 4. Apical view of an internal cast.
FIG. 5. TURRITELLA BURKARTI sp. n. (p. 92).
FIG. 6. VERMETUS CORNEJOI Castillo and Aguilera (p. 92).
FIGS. 7, 8. NATICA WILLIAMSI sp. n. (p. 93).
FIGS. 9, 10. NATICA BILABIATA sp. n. (p. 95).
FIGS. 11, 12. NATICA INFLECTA sp. n. (p. 94).
FIG. 13. CERITHIUM ARCUIFERUM sp. n. (p. 99).
FIG. 14. ACTÆONINA ? MALONIANA sp. n. (p. 99).
FIGS. 15, 16. NATICA FINLAYENSIS sp. n. (p. 94).



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# PLATE XXI.



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# PLATE XXI.

FIGS. 1–3. NERINEA GOODELLII sp. n. (p. 96).

FIGS. 4, 5. NERINEA CIRCUMVOLUTA sp. n. (p. 97).

Fig. 4. Longitudinal section enlarged 2 diameters.

FIGS. 6–9. NERINELLA STANTONI sp. n. (p. 98).

Fig. 8. Fragment enlarged 3 diameters.

Fig. 9. Longitudinal section of same fragment enlarged.

FIG. 10. PSEUDOMELANIA GOODELLII sp. n. (p. 95).



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# PLATE XXII.



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# PLATE XXII.

FIG. 1. NAUTILUS BURKARTI Castillo and Aguilera (p. 100).
FIGS. 2, 3. OPPELIA ? FALLAX Castillo and Aguilera (p. 101).



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# PLATE XXIII.



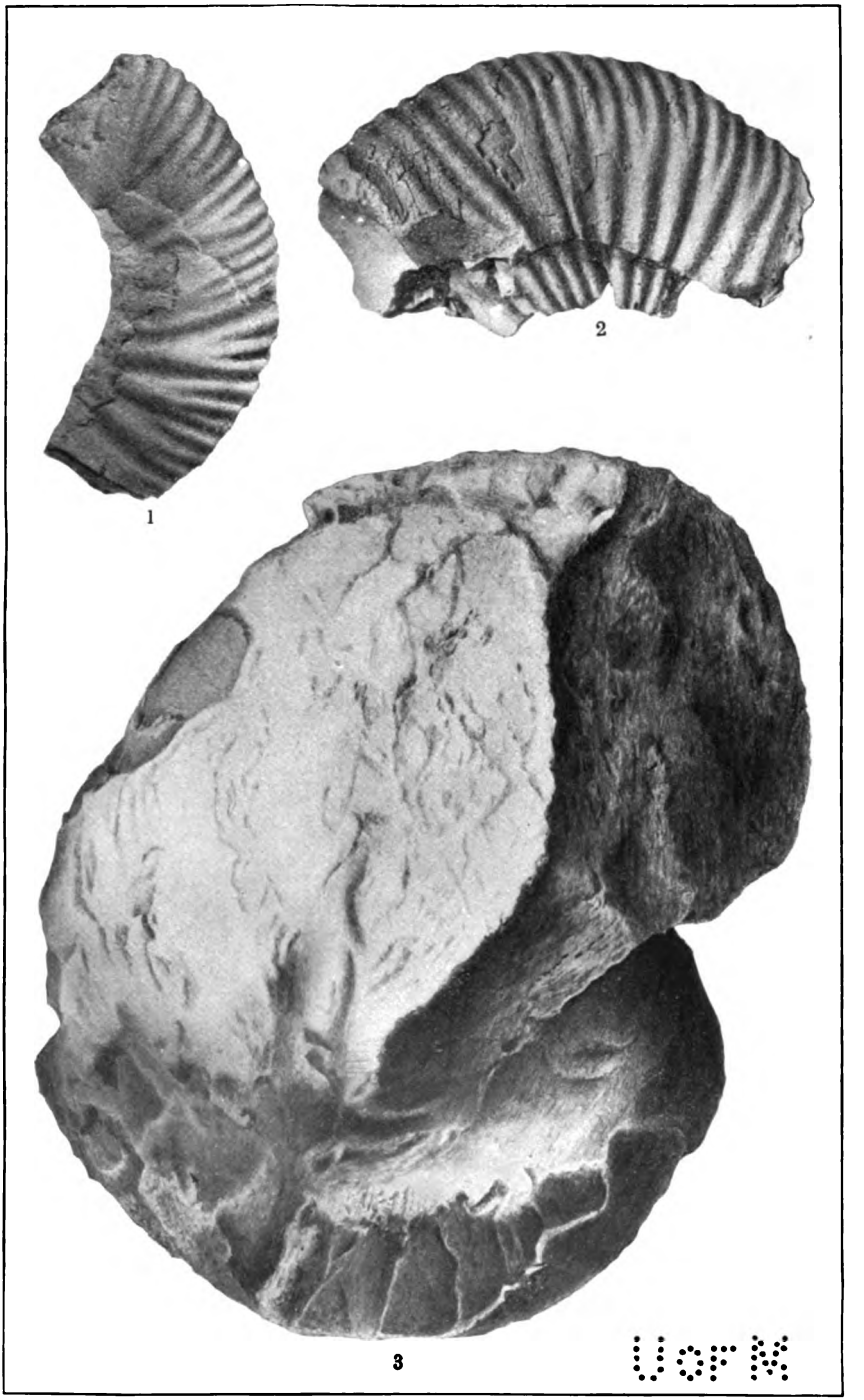
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# PLATE XXIII.

Fig. 1. Perisphinctes potosinus Castillo and Aguilera (p. 105).
Fig. 2. Perisphinctes felixi Castillo and Aguilera (p. 106).
Fig. 3. Nautilus naufragus sp. n. (p. 100).
See Pl. XXIV, fig. 3.



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# PLATE XXIV.



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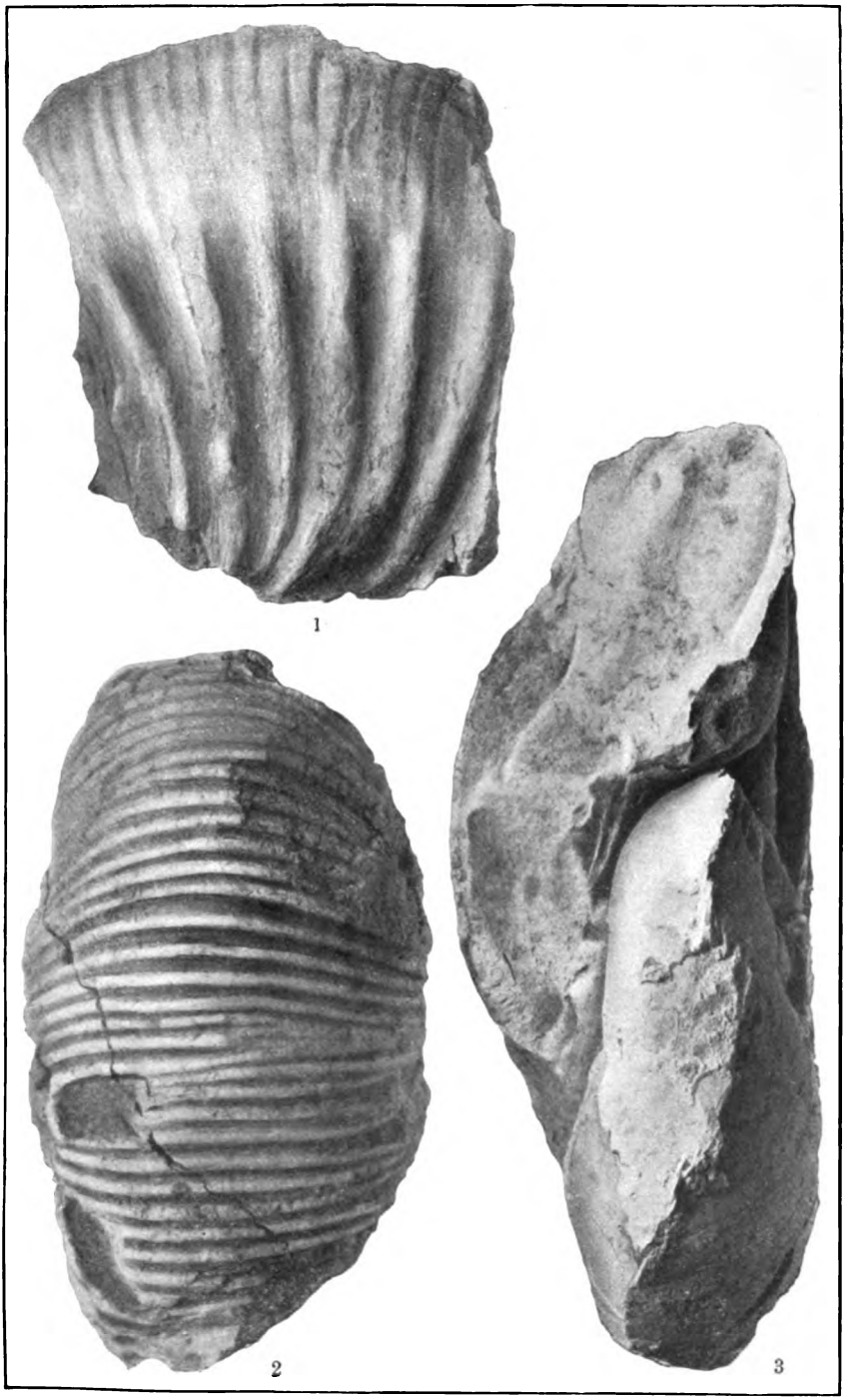
# PLATE XXIV.

FIGS. 1, 2. OLCOSTEPHANUS MALONIANUS sp. n. (p. 103).
Lateral and ventral views of two fragments.

FIG. 3. NAUTILUS NAUFRAGUS sp. n. (p. 100).
Ventral view of specimen represented by Pl. XXIII, fig. 3.



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# PLATE XXV.



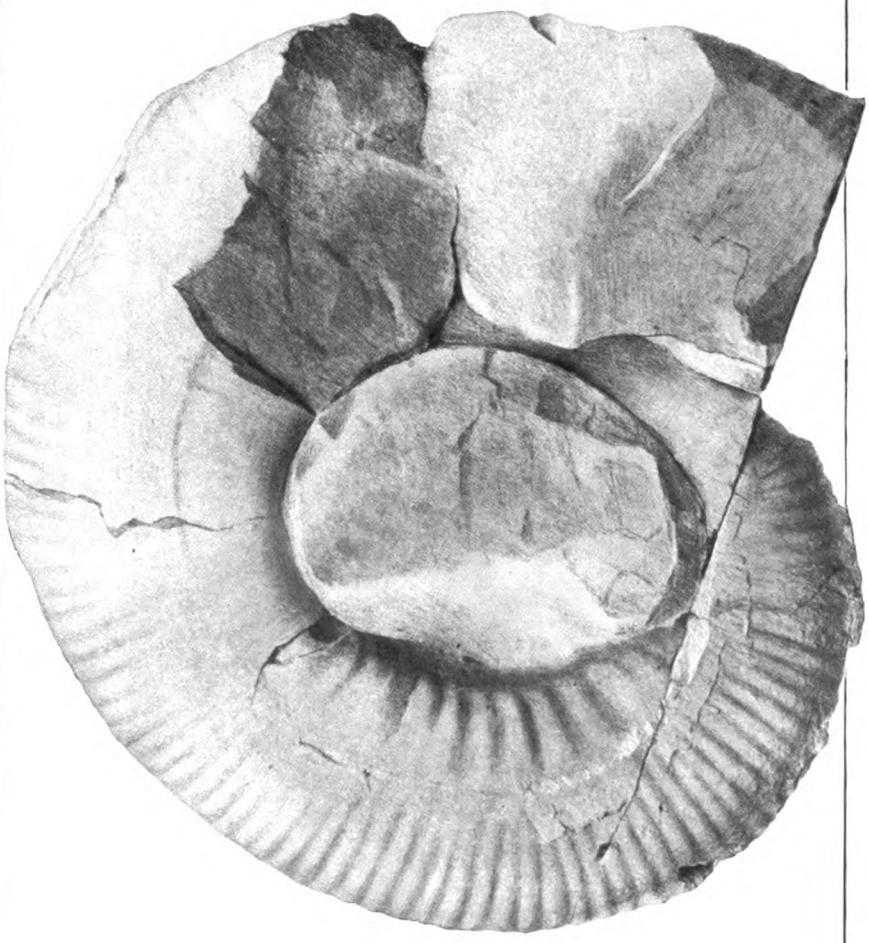
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# PLATE XXV.

FIG. 1. PERISPHINCTES SCHUCHERTI sp. n. (p. 107).
See Pls. XXVI and XXVII for additional figures.



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# PLATE XXVI.



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# PLATE XXVI.

FIGS. 1–3. PERISPHINCTES SCHUCHERTI sp. n. (p. 107).

Fig. 1. Ventral view of specimen figured on Pl. XXV.

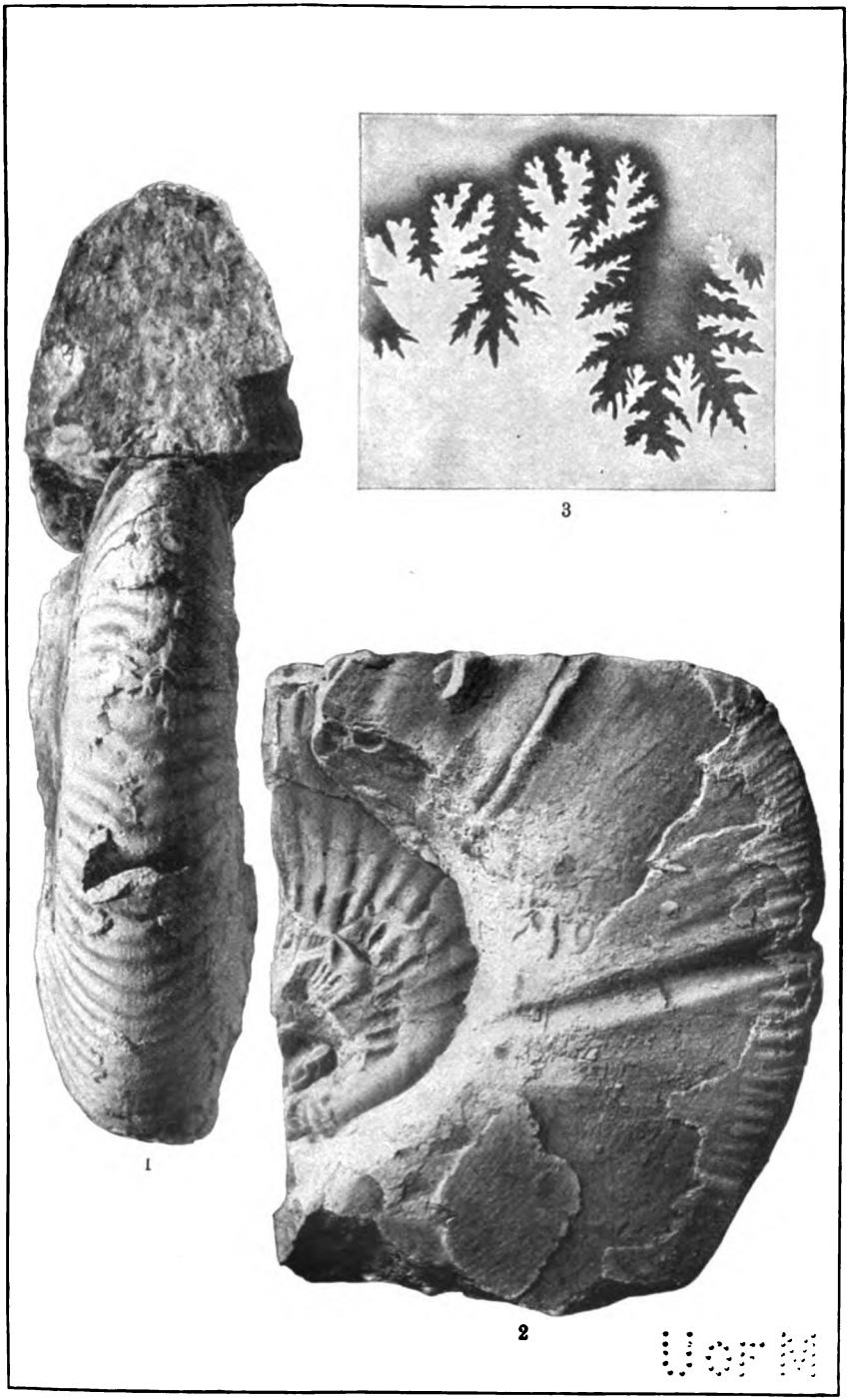
Fig. 2. Side view of smaller specimen.

Fig. 3. Part of suture showing first and second lateral lobes from another specimen enlarged 3 diameters.

See Pl. XXVII for additional figure.



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# PLATE XXVII.



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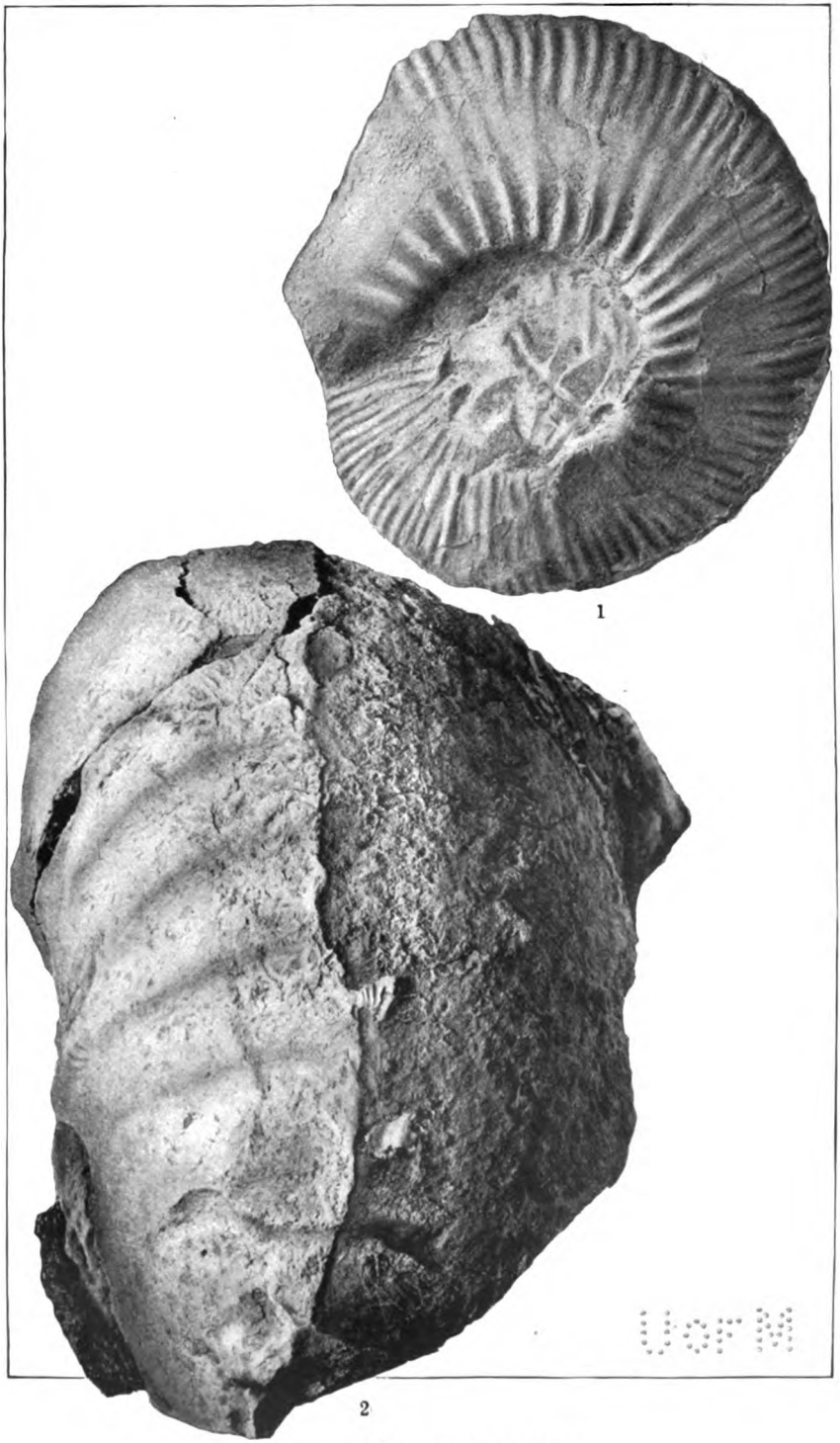
# PLATE XXVII.

FIG. 1. PERISPHINCTES SCHUCHERTI sp. n. (p. 107).
See Pls. XXV and XXVI for additional figures.

FIG. 2. ASPIDOCERAS ALAMITOCENSIS Castillo and Aguilera (p 109).
Ventral view of a fragment.



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# PLATE XXVIII.



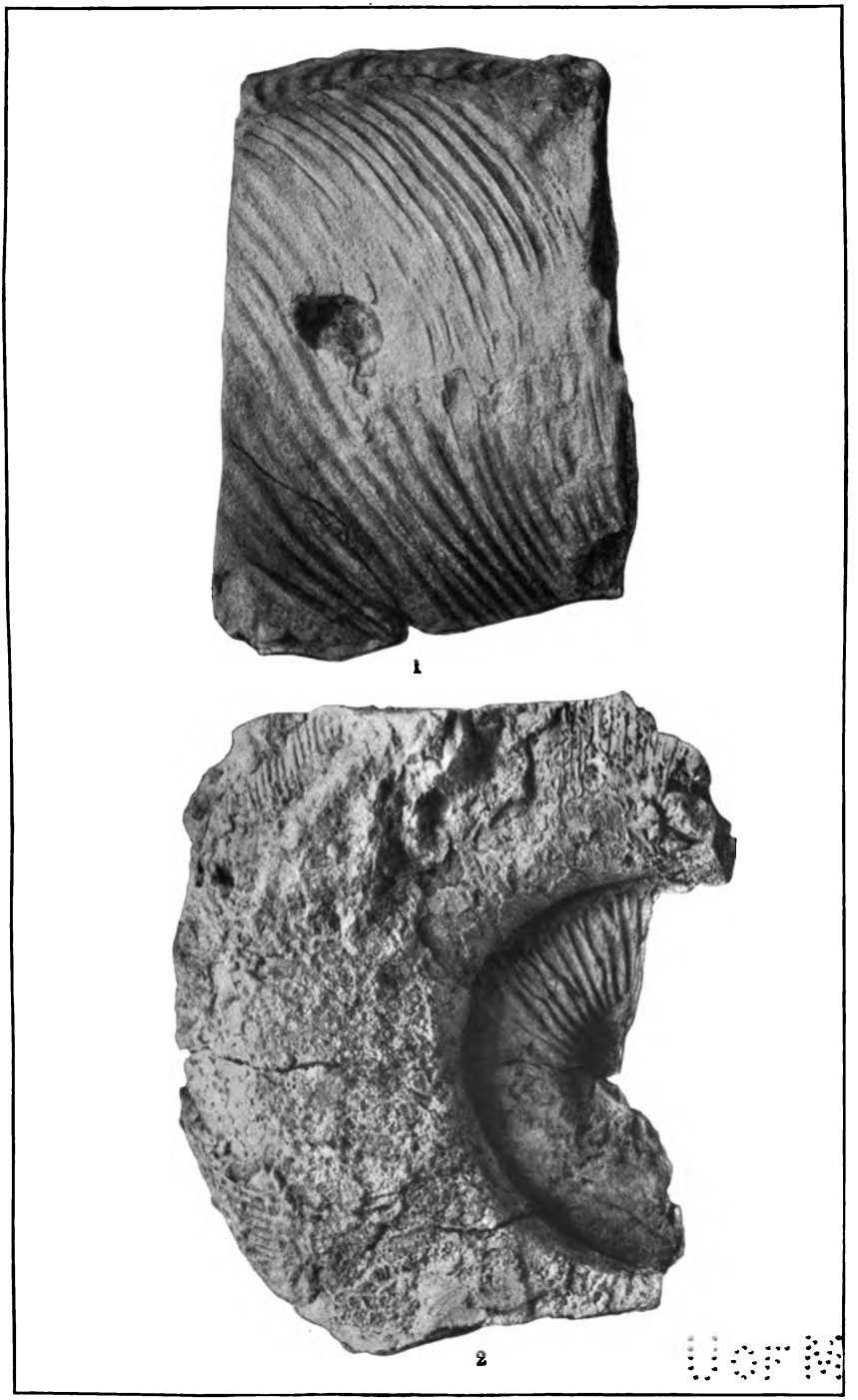
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# PLATE XXVIII.

FIGS. 1, 2. PERISPHINCTES AGUILERAI sp. n. (p. 105).



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# PLATE XXIX.



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# PLATE XXIX.

FIGS. 1, 2. PERISPHINCTES CLARKI sp. n. (p. 103).
Fig. 1. A large imperfect specimen.
Fig. 2. Septum of same, somewhat weathered.

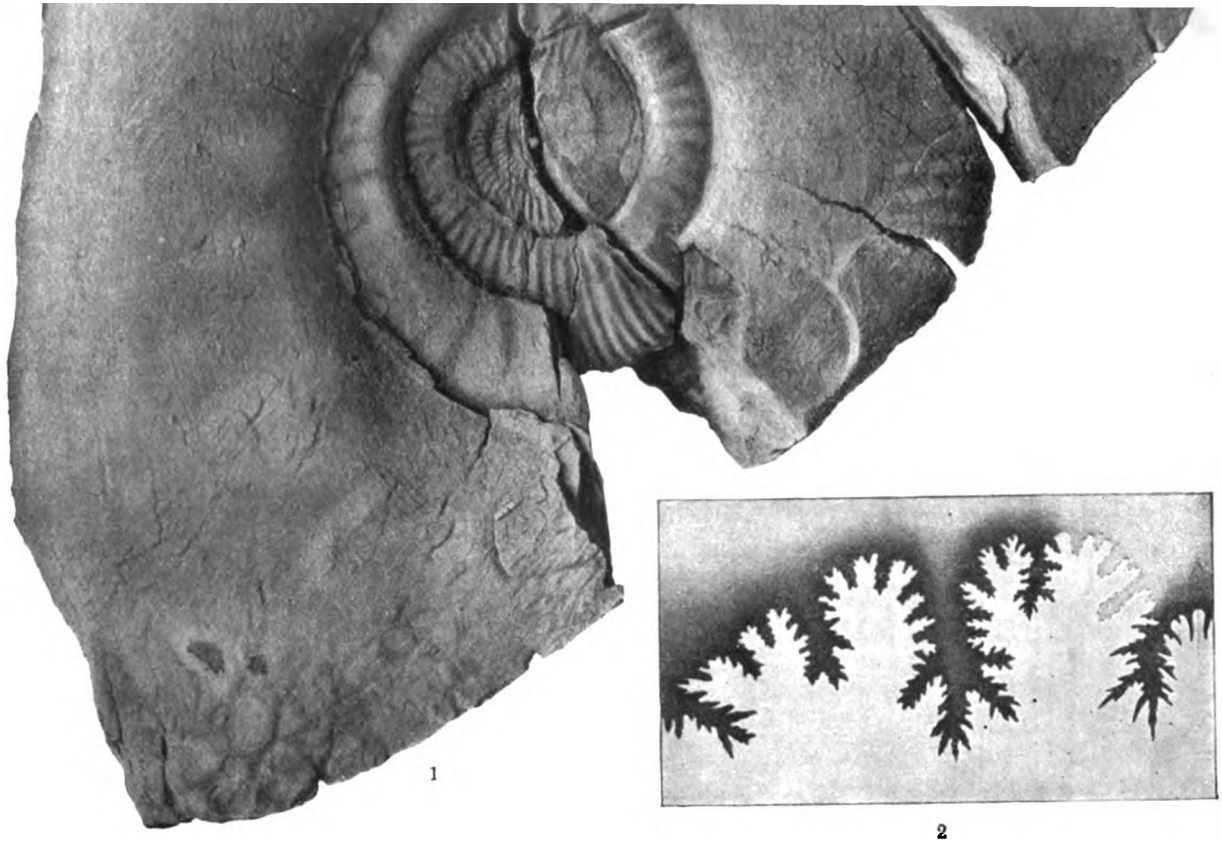


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